THE RESOURCES AGENCY OF CALIFORNIA

Department of Water Resources

BULLETIN No. 111

SACRAMENTO RIVER WATER POLLUTION SURVEY

APPENDIX A

HYDROGRAPHY, HYDROLOGY, AND WATER UTILIZATION

AUGUST 1962

EDMUND G. BROWN
Governor
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WILLIAM E. WARNE
Administrator
The Resources Agency of California
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P A R T 1

H Y D R O G R A P H Y

CHAPTER I. INTRODUCTION

The Sacramento River Water Pollution Survey was conducted over the 300-mile reach between Keswick Reservoir, which provides afterbay regulation of releases from Shasta Dam, and the confluence of the Sacramento and San Joaquin Rivers at Mayberry Slough (Plate 1).

The river may be divided into three major reaches. In the upper reach between Keswick (mile 300) and Hamilton City (mile 200), the river flows through rolling to mountainous country in a steep, well-defined channel with many rapids. Inflows from permanent and intermittent streams and from rising ground water occur in this reach.

Throughout the middle reach, between Hamilton City and Sacramento (mile 60), the river follows a meandering course through a deep and wide alluvial fill and is controlled by extensive levee systems and flood-control bypasses. Most of the side streams in the upper portion of this reach are diverted through Colusa Basin to the west and by Butte Slough and Sutter Basin to the east. There are a number of irrigation diversions and returns. The two major tributaries, the Feather and American Rivers, enter at miles 80 and 61, respectively.

The lower reach, between Sacramento and Mayberry Slough is characterized by distributary flows through various waterways in the Sacramento-San Joaquin Delta. The major diversion from the river through the Delta Cross Channel (mile 27.4) provides water to the San Joaquin Valley through the U. S. Bureau of Reclamation's Delta-Mendota Canal. Tidal action causes flow reversals as far upstream as Clarksburg (mile 43) and affects water levels and velocities as far upstream as Verona (mile 80). The maximum flow reversals occur in the vicinity of Isleton (mile 19) where the channel is narrowest.

CHAPTER II. BASIC DATA

For the purposes of defining hydrographic characteristics, the river was divided into two reaches, Keswick to Sacramento and Sacramento to Mayberry Slough.

River Mileages

River miles to various hydrographic and cultural features were determined from the most recent U. S. Geological Survey 7-1/2-minute quadrangle sheets. Zero mileage was established at Collinsville and distances obtained by map measure along the approximate center of the river are listed in Table 1.1.

Flows

U. S. Bureau of Reclamation records for releases from Keswick and Folsom Dams, stage-discharge data for 69 U. S. Geological Survey gaging stations (Table 1.2) and the Department of Water Resources Bulletin No. 23 series, "Surface Water Flows," were utilized.

Below Sacramento, the assumed distribution of the mean net flow past Sacramento (at "I" Street) within the Delta waterways is based upon unpublished departmental studies made in connection with investigations of salinity barriers in the San Francisco Bay complex. These studies were based on computations of changes in channel storage throughout a 28-day cycle.

Cross-Sections

Between Keswick and Sacramento, 126 cross-sections were determined by use of a fathometer, transit, and stadia board. Wherever possible, cross-sections were made at active stream-gaging stations.

Below Sacramento, data from 79 cross-sections obtained in 1927-30 and reviewed in 1940 by the U. S. Corps of Engineers were utilized.

Velocities

At each cross-section above Sacramento, a single measurement with a current meter was made about one foot below the water surface in the main thread of the river. At active stream gaging stations, values of mean velocity and flows were obtained from recent current meter ratings of the control section.

Water Surface Areas

Water surface areas were obtained from 1:24,000 aerial photographs taken in 1949 by the U. S. Bureau of Reclamation and calculated from rating curves for the gaging stations.

Locations of Rapids

Aerial photographs by the U. S. Bureau of Reclamation and the California Department of Fish and Game and field observations were used to locate rapids which are listed in Table 1.3.

Water Surface Slopes

Approximate water surface slopes are based on U.S.G.S. topographic maps, earlier studies of surface water profiles, U. S. Corps of Engineers flood-plain computations, and rating curves for active gaging stations. Average slopes over one to 26-mile reaches are presented in Table 1.4 for purposes of correlation with data on bottom sediments presented in Appendix D. They are not adequate for detailed hydraulic analysis of short reaches.

CHAPTER III. METHODS AND RESULTS

The available data required that different computational methods be used for the reaches of the river above and below Sacramento.

Keswick to Sacramento

Hydraulic characteristics were computed for each of 126 cross sections between Keswick and Sacramento (or the reach of river between cross sections) for six different flows (Table 1.5). In general, these characteristics are a function of the flow in the Sacramento River only, although high flows in the Feather River may cause some backwater effects on a few cross sections above the junction of the Feather River with the Sacramento River.

Basic Approach

Limitations on funds and time made it necessary to develop the hydraulic characteristics for six different flows from a single visit to each cross section. Examination of rating curves for individual gaging stations indicated that the relationship between flow and cross section and between flow and mean velocity remains fairly constant. Accordingly, all computations are based on the flow-velocity relationships rather than on water surface slopes.

Velocity-Flow Curves

For each active gaging station on the river, values of Q and V from recent current meter ratings of the control section were plotted, and smooth curves of velocity vs. flow were drawn.

Velocity Profiles

On a chart with "miles from Collinsville" as the abscissa, and "velocity" as the ordinate, velocity profiles were drawn for each quantity of flow shown in Table 1.5. Information for plotting these velocity profiles came from three sources:

(1) A velocity for each quantity of flow was taken from the velocity-flow curve at each active gaging station. This gave a point on each profile at each active gaging station.

(2) A mean velocity based on the single measurement of velocity at each cross section was used as a guide for positioning profiles between active gaging stations. The mean velocity was obtained by applying a ratio to the single measurement of velocity. This ratio was determined by dividing the mean velocity from a rating measurement of a nearby gaging station by a single rating velocity measurement made under the same criteria as the point measurement at the cross section.

(3) The beginnings and ends of all rapids were considered points of discontinuity in the velocity profiles.

Cross Section Curves

From the cross sections, curves of area, wetted perimeter, and width were plotted against elevation above the bottom of the section. For each flow (Q) in Table 1.5, a velocity was read from the velocity profiles and an area (A) computed ($A = Q/V$). From the cross section curves, a width (W), and a wetted perimeter (P), were read at the same elevation as each of the areas. From these, the hydraulic radius ($R = A/P$) and mean depth ($D = A/W$) were computed.

Surface Areas

Each cross section was located on an aerial photograph of known scale, and the water surface areas between cross sections planimetered. The flow in the reach was estimated from nearby gage records and the corresponding surface widths at the end sections were computed. The ratio of the average width from the aerial photograph divided by the average width at the end sections provided a width correction factor. This factor was then applied to cross section widths at various flows, and the surface area computed.

Travel Times

Travel times were computed for each reach between cross sections and for each flow in Table 1.5 by dividing the length of the reach by the average of end section velocities.

Sacramento to Collinsville

The available data precluded the determination of hydraulic characteristics in the lower reach for a wide range of flows. Accordingly, values shown for this reach of the river are based on a mean net flow of 10,000 cfs passing Sacramento, with the Delta Cross Channel gates open, and no flow from Cache Creek.

The Department of Water Resources, in its San Francisco Bay Barrier Investigation, has derived curves which show the division of water (net mean flow) between the main Sacramento River and branch channels, for a number of flows passing Sacramento. By beginning at Sacramento with a flow of 10,000 cfs, and subtracting or adding flows at each branch channel as read from the above-mentioned curves, a net mean flow was found for each reach of the river between cross sections 125 and 205. These values are shown in the last column of Table 1.6.

Physical dimensions of each cross section in this major reach of the river were computed by the U. S. Army Corps of Engineers for a water surface elevation of 0, USGS datum. For the present study, these physical dimensions were corrected to a mean water surface elevation for a net mean flow of 10,000 cfs at Sacramento.

Velocity and Travel Time

The velocity was found for each cross section by dividing Q by A. The net travel time for each reach was determined from the average of the velocities at the end sections.

Typical Travel Times

The difference between actual hour by hour flow and net mean flow is illustrated by Figure 1.1. This figure is based on hourly velocities throughout the lower reach for a mean net flow of 10,700 cfs past Sacramento. It should be noted that this chart is useful for illustration only. Computations were made on the assumption that a 25-hour pattern of tidal velocities (approximately one lunar day) would be repeated over and over. A different but similar curve would be produced if the accumulation of travel time had begun at a different phase of the 25-hour cycle, or if the 25-hour cycle of velocities had been prepared for a different phase of the moon. The curve was produced by graphical methods, which are considered sufficiently accurate for an illustrative curve. The accumulated travel time based on net mean flow for 10,000 cfs at Sacramento (see Table 1.6) has been superimposed on this chart, for comparison. The greatest current reversals are shown to occur near Isleton where the channel narrows down.

Direct Observation of Travel Times

During the Sacramento River Water Pollution Survey, continuous electrical conductivity recorders were installed on the river at Red Bluff (mile 244.1), Colusa (mile 144.1), above Colusa Basin Drain (mile 90.5), Sacramento Weir (mile 63.6), Freeport (mile 46.4), and Walnut Grove (mile 26.9). Data from these recorders are presented in Appendix B. Data from an additional recorder installed at Isleton (mile 18.8) for a short period are available in the department's files.

Irrigation return waters are pumped from Reclamation District No. 108 at mile 100.1. These waters have specific conductance values of about 500 micromhos and may be readily identified on downstream conductivity records where the background values are generally between 120 and 200 micromhos. Pumping is done during the night in order to take advantage of off-peak power rates. The conductivity records thus provide a direct measure of travel times of slugs of drainage water between mile 90.5 and mile 18.8. Travel times determined in this manner for various flows are presented in Figure 2.2. The accumulated travel times for 10,000 cfs listed in Table 1.6 are also shown on the figure and indicate excellent agreement between computed and observed values.

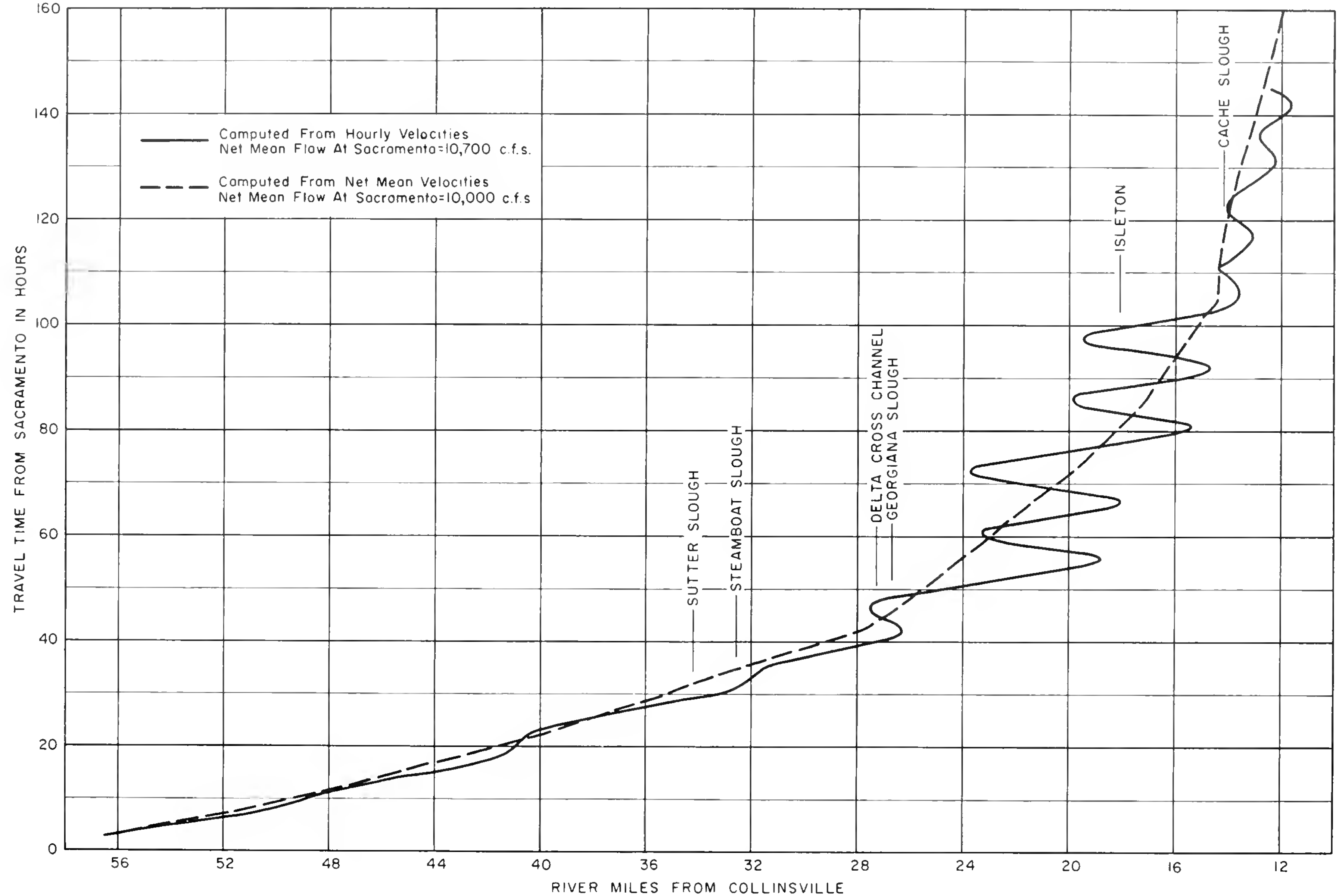


Figure I.I. TYPICAL TRAVEL TIMES FROM SACRAMENTO BASED ON CHANGES IN CHANNEL STORAGE

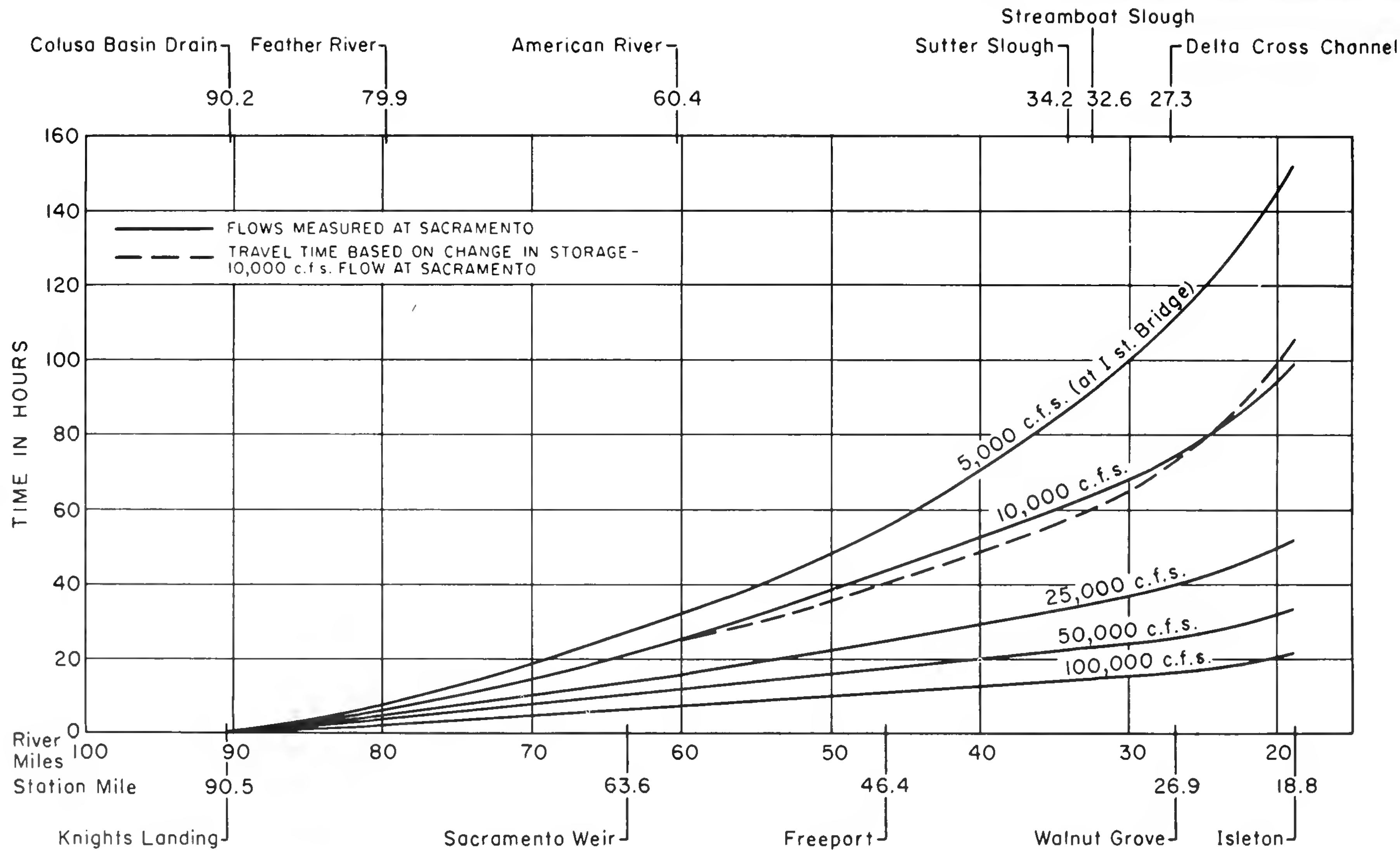


Figure 1.2. TRAVEL TIMES FROM KNIGHTS LANDING BASED ON CONDUCTIVITY RECORDS

Table 1.1

SACRAMENTO RIVER WATER POLLUTION SURVEY
RIVER MILEAGES OF PRINCIPAL POINTS

	Mileages
Tide gaging station - at Collinsville	-0.19
USCE "0" Mileage at Mouth of San Joaquin River	0
Collinsville	0.17
Power line crossing	3.90
Sacramento River above Mayberry Slough (Sampling Station)	3.96
Toland Landing	6.27
Power line crossing	6.46
Threemile Slough	9.21
Tide gaging station - at Rio Vista	11.77
Rio Vista	12.22
Rio Vista Bridge- Hwy. 12	12.83
Sacramento River at Rio Vista Bridge (Sampling Station)	12.83
Steamboat Slough	14.18
Power line crossing	16.56
Tide gaging station - at Isleton	17.50
Isleton Bridge - Hwy. 24	18.78
Sacramento River at Isleton Bridge (Sampling Station)	18.78
Ryde	24.30
Tide gaging station - at Walnut Grove, Georgiana Slough	26.67
Bridge - Walnut Grove	26.86
Delta Cross Channel	27.27
Sacramento River above Delta Cross Channel (Sampling Station)	27.38
Locke	27.46
Vorden	30.08
Power line crossing	31.58
Steamboat Slough	32.60
Bridge - Paintersville	33.58
Sutter Slough	34.19
Courtland	34.55
Tide gaging station - at Snodgrass Slough	37.11
Sacramento River at Snodgrass Slough (Sampling Station)	37.21
Hood	38.60
Clarksburg	42.42
Tide gaging station - at Clarksburg	42.89
Crystal Sugar Waste Discharge	43.26
Sacramento River above Clarksburg (Sampling Station)	43.44
Bridge - Freeport	46.36
Sacramento River at Freeport Bridge (Sampling Station)	46.36
Power line crossing	47.16
Tide gaging station - near Freeport	48.94

Table 1.1

(continued)

	Mileages
Riverview (Sacramento Sewage Treatment Plant)	54.09
West Sacramento Discharge	58.00
Tower Bridge - Hwy. 40	59.23
"I" Street Bridge - Hwy. 16	59.63
Gaging station - at Sacramento	59.82
Intake - City of Sacramento	60.14
American River	60.36
Canal	60.92
R. D. 1000 Drain (2nd Bannon Slough)	61.51
Sacramento River at Bryte Laboratory (Sampling Station)	62.56
Gaging station - at Sacramento Weir	63.58
Pumping Plant No. 3	66.32
5-foot contour crossing	70.61
Elkhorn Ferry	71.02
Elkhorn Pumping Plant	73.52
R. D. 1000 Drain at Pritchard	75.46
10-foot contour crossing	78.42
Vernon Landing	79.13
Natomas Cross Canal	79.13
Gaging station - at Verona	79.13
Power line crossing	79.90
Fremont Landing	79.92
Feather River, Verona	80.00
Sacramento Slough	80.75
Sacramento River above Sacramento Slough (Sampling Station)	81.12
Gaging station - at Fremont Weir E.E.	82.06
Gaging station - at Fremont Weir W.E.	84.48
Pumping station	88.27
15-foot contour crossing	89.73
Southern Pacific Railroad Bridge	89.96
Gaging station - at Knights Landing	89.98
Bridge - Hwy. 24	90.15
Colusa Basin Drain	90.23
Sacramento River above Colusa Basin Drain (Sampling Station) . . .	90.50
Power line crossing	91.46
Pump R. D. 787 Drain (above 4-mile bend)	93.60
Pumphouse R. D. 2047	99.02
Pumphouse R. D. 108 Drain	100.06
Gaging station - above R. D. 108 Drain	102.47
Tyndall Landing	102.47

Table 1.1

(continued)

	Mileages
20-foot contour crossing	103.10
Kirkville	105.09
Howells Landing	109.63
Pump, Poffenbergs Landing	110.33
Boyers Landing	111.44
Millers Landing	111.83
25-foot contour crossing	116.55
Fraziers Landing	117.66
Gaging station - below Wilkins Slough	118.11
Sacramento River below Wilkins Slough (Sampling Station)	118.11
Pumping station - R. D. 108 Supply	118.31
Pumping station - Sutter Mutual Water Company	118.96
Gaging station - below Tisdale Weir	118.96
Gaging station - at Tisdale Weir	119.40
Pumping station - R. D. 70 Drain (below Grimes)	124.15
Grand Island	124.46
Grimes	125.85
30-foot contour crossing	127.04
Bridge - Hwy. 20	134.60
Gaging station - at Meridian	134.60
35-foot contour crossing	137.44
Gaging station - at Butte Slough Outfall Gates	138.86
Gaging station - at Colusa	144.09
Bridge - at Colusa	144.11
Sacramento River at Colusa Bridge (Sampling Station)	144.11
Colusa	144.67
40-foot contour crossing	145.17
Gaging station - at Colusa Weir	146.58
45-foot contour crossing	150.21
50-foot contour crossing	155.23
55-foot contour crossing - Compton Landing	158.14
Gaging station - opposite Moulton Weir	158.21
Gaging station - (Removed on May 27, 1955)	158.66
60-foot contour crossing	162.23
Princeton	163.70
Princeton Ferry	164.11
Pumphouse - R. D. 1004	164.25
65-foot contour crossing	166.50
Sacramento River at Butte City Bridge (Sampling Station)	168.25
Bridge	168.25
Gaging station - at Butte City	168.28
Butte City	168.68
70-foot contour crossing	169.81
75-foot contour crossing	172.67
80-foot contour crossing	176.61

Table 1.1

(continued)

	Mileages
Sidds Landing	177.60
Jacinto (Actual location 0.22 mile down cutoff)	180.14
80-foot contour crossing	180.33
Hites Landing	181.81
90-foot contour crossing	182.81
Parrott Landing	183.46
Gaging station - at Ord Ferry	184.36
Sacramento River at Ord Ferry (Sampling Station)	184.48
95-foot contour crossing	185.21
100-foot contour crossing	188.32
Stony Creek	190.84
105-foot contour crossing	190.96
110-foot contour crossing	193.13
Big Chico Creek	193.86
Chico Landing (site)	194.76
115-foot contour crossing	195.41
120-foot contour crossing	197.00
Pine Creek	197.11
Gaging station - at Hamilton City	199.55
Sacramento River at Hamilton City Bridge (Sampling Station)	199.59
Gianella Bridge - Hwy. 32	199.59
125-foot contour crossing	199.95
McIntosh Landing	202.11
130-foot contour crossing	202.73
135-foot contour crossing	203.74
Pumping station - Glenn-Colusa I. D.	205.06
140-foot contour crossing	206.98
Rice Creek	207.22
145-foot contour crossing	207.81
Discus Slough	208.36
150-foot contour crossing	210.28
Merrills Landing	212.61
Hoag Slough	213.30
155-foot contour crossing	213.39
Jewett Creek	214.53
160-foot contour crossing	215.14
Squaw Hill, Woodson Bridge - Vina Bridge	217.61
Sacramento River at Vina Bridge (Sampling Station)	217.61
Kopta Slough	217.67
Gaging station - at Vina	217.67
165-foot contour crossing	218.30
Deer Creek, China Creek	219.07
170-foot contour crossing	220.00
Toomes Creek	221.03
175-foot contour crossing	221.77

Table 1.1

(continued)

	Mileages
180-foot contour crossing	223.54
Thomes Creek	224.44
185-foot contour crossing	225.21
McClure Creek	225.73
Millrace	226.68
190-foot contour crossing	227.46
Tehama	228.17
Tehama Bridge	228.40
Sacramento River at Tehama Bridge (Alternate Site)	228.40
Mill Creek	229.05
195-foot contour crossing	229.07
Elder Creek	229.44
Sacramento River above Elder Creek (Sampling Station)	229.81
North Fork Mill Creek	229.96
200-foot contour crossing	230.70
Dye Creek	231.18
Oat Creek	231.98
205-foot contour crossing	232.02
210-foot contour crossing	233.25
Antelope Creek	233.50
215-foot contour crossing	234.50
Butler Slough	235.11
220-foot contour crossing	235.73
225-foot contour crossing	236.67
Craig Creek	238.11
230-foot contour crossing	238.28
Salt Creek	238.98
235-foot contour crossing	240.54
Paynes Creek Slough, Samson Slough	241.19
Gaging station - at Red Bluff (U.S.B.R.)	241.71
Red Bank Creek	241.92
240-foot contour crossing	242.02
Red Bluff Waste Discharge	242.82
Brickyard Creek	243.66
Reeds Creek	243.66
Gaging station - at Red Bluff (U.S.B.R.)	244.03
Red Bluff Bridge - Hwy. 99E & 36	244.11
Gaging station - at Red Bluff	244.11
245-foot contour crossing	244.90
Dibble Creek	245.38

Table 1.1

(continued)

	Mileages
Blue Tent Creek	246.50
250-foot contour crossing	247.25
Gaging station - near Red Bluff	249.04
Sevenmile Creek	249.54
255-foot contour crossing	250.33
Creek from Hog Lake	250.98
Paynes Creek	251.67
265-foot contour crossing	253.60
270-foot contour crossing	254.29
Spring Creek	256.21
Bend Bridge	256.33
Sacramento River at Bend Bridge (Sampling Station)	256.33
Power line crossing	258.50
Creek, Table Mountain Lake	262.03
300-foot contour crossing	262.13
Inks Creek	263.32
Jellys Ferry Bridge	265.52
Frazier Creek	266.64
325-foot contour crossing	268.00
Battle Creek	270.10
Cottonwood Creek	272.36
Anderson Creek	272.60
350-foot contour crossing	273.56
Fish counting station, return canal	274.85
Gaging station - at Balls Ferry	274.85
Balls Ferry Bridge	274.98
Sacramento River at Balls Ferry Bridge (Sampling Station)	274.98
Ash Creek	275.15
Bear Creek	276.45
Power line crossing	277.90
Cow Creek	278.93
Anderson-Palo Cedro Bridge	279.65
Stillwater Creek	279.75
375-foot contour crossing	279.80
Riverview Ranch Bridge	283.00
Churn Creek	283.46
Power line crossing	283.80
Power line crossing	284.31
400-foot contour crossing	285.57
Sacramento River above Churn Creek (Sampling Station)	285.90

Table 1.1

(continued)

	Mileages
Middle Stake Fish Weir (Abandoned)	285.90
420-foot contour crossing	287.83
Clear Creek	288.12
Olney Creek	288.33
430-foot contour crossing	289.38
Gaging station - near Redding	290.87
440-foot contour crossing	290.92
450-foot contour crossing	292.08
Sewage Treatment Plant - Redding	293.77
Cypress Avenue Bridge	293.92
460-foot contour crossing	294.00
470-foot contour crossing	295.72
Sulfur Creek	296.33
Bridge - Hwy. 99	297.15
480-foot contour crossing, Diversion	297.28
Redding Diversion Dam	297.28
Southern Pacific Railroad Bridge	297.60
Sacramento River at Redding Diversion Dam (Sampling Station)	297.70
Bridge	297.70
Pumphouse - City of Redding Intake	298.00
Gaging station - at Keswick (Auxiliary)	298.00
Power line crossing	299.50
Middle Creek	299.73
Gaging station - at Keswick	300.11
Rock Creek	300.60
Keswick Dam (roadway)	300.90
Power line crossing	302.08
Spring Creek	302.25
Flat Creek	303.04
Boat Landing	304.58
Creek	305.38
Sacramento River at Matheson (Sampling Station)	305.68
Motion Creek	307.54
Cornish Creek	308.11
Cottonwood Creek	308.76
Moccasin Creek	309.33
Bridge	310.46
Shasta Dam (roadway)	310.81

Table 1.2

SACRAMENTO RIVER WATER POLLUTION SURVEY

Inventory of Active Stream Gaging Stations
August 1960 Rev.

No.	River mileage	Station names	Type of record	Agency
1	300.1	Sacramento R. at Keswick	RC	USGS
2	290.9	Sacramento R. near Redding	RC[1/]	DWR
3	288.1	Clear Cr. near Igo (10.5)	RC	USGS
4	278.9	Cow Cr. near Millville (3.0)	RC	USGS
5	276.4	Bear Cr. near Millville (10.0)	RC	DWR
6	274.8	Sacramento R. at Balls Ferry	RC[2/]	DWR
7	272.4	Cottonwood Cr. near Cottonwood (2.4)	RC	USGS
8	270.1	Battle Cr. near Cottonwood (6.3)	RC	USGS
9	251.7	Paynes Cr. near Red Bluff (0.4)	RC	USGS
10	249.0	Sacramento R. near Red Bluff	RC	USGS
11	244.1	Sacramento R. at Red Bluff	R	DWR
12	244.0	Sacramento R. at Red Bluff (Boat landing)	R	USBR
13	241.9	Red Bank Cr. near Red Bluff (15.8)	RC	DWR
14	241.7	Sacramento R. at Red Bank Creek	R	USBR
15	233.5	Antelope Cr. near Red Bluff (9.7)	RC	USGS
16	230.0	North Fork Mill Cr. near Los Molinos (1.7)	RC	DWR
17	229.4	Elder Cr. at Gerber (3.5)	RC	USGS
18	229.0	Mill Cr. near Mouth (1.0)	R	DWR
19	229.0	Mill Cr. near Los Molinos (5.5)	RC	USGS
20	224.4	Thomes Cr. at Paskenta (30.7)	RC	USGS
21	219.1	Deer Cr. near Vina (11.7)	RC	USGS
22	217.7	Sacramento R. at Vina Bridge	RC	DWR
23	199.6	Sacramento R. at Hamilton City Bridge	RC	DWR
24	193.9	Big Chico Cr. at Chico (5.7)	RC	DWR
25	193.9	Lindo Channel near Chico (Grape Way) (2.9)	RC	DWR
26	190.8	Stony Cr. near Hamilton City (6.0)	RC	USGS
27	184.4	Sacramento R. at Ord Ferry	RC	DWR
28	168.3	Sacramento R. at Butte City	RC	USGS
29	158.2	Sacramento R. opposite Moulton Weir	RC[2/]	DWR
30	159	Moulton Weir Spill to Butte Basin	RC	DWR
31	147	Colusa Weir Spill to Butte Basin	RC	DWR
32	144.1	Sacramento R. at Colusa	RC	USGS
33	138.9	Sacramento R. at Butte Slough Outfall Gates	S	DWR
34	138.9	Butte Slough at Outfall Gates (0.2)	RC	DWR
35	134.6	Sacramento River at Meridian	RC[1/]	DWR

Table 1.2

SACRAMENTO RIVER WATER POLLUTION SURVEY

Inventory of Active Stream Gaging Stations
August 1960 Rev.
(continued)

No.	River mileage	Station names	Type of record	Agency
36	124.2	R. D. 70 Drainage to S. R. (below Grimes)	PC	DWR
37	119.4	Sacramento R. at Tisdale Weir	R 3/	DWR
38	119	Tisdale Weir Spill to Sutter Bypass	RC	DWR
39	119.0	Sacramento R. below Tisdale Weir (not active)	R	DWR
40	118.1	Sacramento R. below Wilkins Slough	RC	USGS
41	102.5	Sacramento R. above R. D. 108 Drain	RC 2/	DWR
42	100.1	R. D. 108 Drainage to S. R. (at Rough and Ready Bend)	PC	DWR
43	93.6	R. D. 787 Drainage to S. R. (above 4 mile Bend)	PC 4/	DWR
44	90.2	Colusa Basin Drain at Knights Landing (0.3)	RC	DWR
45	90.2	Sycamore Slough near Knights Landing	PC 4/	DWR
46	90.0	Sacramento R. at Knights Landing	RC	USGS
47	84.5	Sacramento R. at Fremont Weir (West End)	R	DWR
48	84	Fremont Weir Spill to Yolo Bypass	RC	DWR
49	80.8	Sacramento Slough at Sacramento R. (0.7)	RC 5/	DWR
50	79.9	Feather River at Nicolaus (9.5)	RC	USGS 6/
51	79.1	Sacramento R. at Verona	RC	USGS
52	79.1	R. D. 1001 Drainage to Natomas Cross Canal (1.0)	PC	DWR
53	75.5	R. D. 1000 Drainage to S. R. (Pritchard Lake)	PC	DWR
54	63.6	Sacramento R. at Sacramento Weir	R	DWR
55	63	Sacramento Weir Spill to Yolo Bypass	RC	DWR
56	61.5	R. D. 1000 Drainage to S. R. (Second Bannon Slough)	PC	DWR
57	60.4	American R. at Fair Oaks (20.2)	RC	USGS
58	59.6	Sacramento R. at Sacramento	RC	USGS 6/
59	48.9	Sacramento R. near Freeport	R	USGS
60	42.9	Sacramento R. at Clarksburg	R	DWR 7/
61	37.1	Sacramento R. at Snodgrass Slough	R	DWR
62	26.7	Sacramento R. at Walnut Grove	R	DWR
63	17.5	Sacramento R. at Isleton	R	USBR
64	14.2	Cache Cr. at Yolo (via Yolo Bypass)	RC	USGS
65	14.2	Putah Cr. near Davis (via Yolo Bypass)	RC	USGS
66	14.2	Yolo Bypass near Woodland	RC	USGS
67	11.8	Sacramento R. at Rio Vista	R	USCE
68	9.2	Threemile Slough at Sacramento R.	R	DWR
69	-0.2	Sacramento R. at Collinsville	R	DWR

Table 1.2

SACRAMENTO RIVER WATER POLLUTION SURVEY

Inventory of Active Stream Gaging Stations
August 1960 Rev.
(continued)

The following symbols are used to indicate the type of record for each stream gaging station:

RC - A continuous water stage recorder stream gaging station with computed records.

R - A continuous water stage recorder stream gaging station with uncomputed records.

SC - A water stage (Staff gage only) stream gaging station with periodic readings and computed records.

S - A water stage (Staff gage only) stream gaging station with periodic readings and uncomputed records.

PC - A stream gaging station based on pumping plant operation readings with daily or monthly computed records.

Footnotes

1/ Proposed stage only September 30, 1960, presently computed for the irrigation season only.

2/ Computed record during irrigation season only.

3/ Recorder does not function until river flow is within 3 feet of the Tisdale Weir Crest.

4/ Monthly totals only.

5/ No records for high flows, computed low flows only.

6/ DWR computes preliminary record.

7/ Proposed abandonment September 30, 1960.

NOTE: (Mileages shown in parenthesis following tributary stations indicate travel distances from the station site to the Sacramento River.)

Table 1.3

SACRAMENTO RIVER WATER POLLUTION SURVEY
LOCATION OF MAJOR RAPIDS

River Mileages			
Beginning	End	Beginning	End
301.86 (below Keswick Dam)	301.65	261.65	261.40
299.82	299.61	253.80 (China Rapids)	252.58
297.28 (below Redding Div. Dam)	296.90	233.09	232.73
295.89	295.63	231.07	230.73
292.66	292.51	230.42	229.95
291.72	291.61	225.87	225.66
280.70	280.59	201.88	201.48
279.08	278.91	203.17	202.85
277.74	277.67	208.30	207.83
264.97	264.40	127.14	196.37
262.77	262.62	184.80	184.55

Table 1.4

SACRAMENTO RIVER WATER POLLUTION SURVEY
APPROXIMATE WATER SURFACE SLOPES
BETWEEN BIOLOGICAL SAMPLING STATIONS
Based Upon 10,000 cfs Flow

Sacramento River sampling station	Nearest cross section number	River mile	Length of reach miles	Approximate slope
Above Spring Creek	1	305.7	8.0	-----*
Above Redding	5	297.7	2.5	.0011
At Redding	8	295.2	1.2	.0012
At Redding	9	294.0	8.1	.0013
Above Churn Creek	16	285.9	6.8	.0009
Below Anderson	20	279.1	4.1	.0008
Balls Ferry	22	275.0	18.7	.0008
Bend Bridge	33	256.3	2.9	.0007
Big Bend	35	253.4	12.4	.0004
Below Red Bluff	43	241.0	11.2	.0006
Above Elder Creek	49	229.8	12.2	.0005
Vina Bridge	59	217.6	18.0	.0004
Hamilton City	67	199.6	15.1	.0004
Ord Ferry	74	184.5	16.3	.0003
Butte City	82	168.2	24.1	.0002
Colusa	92	144.1	26.0	.00010
Below Wilkins Slough	103	118.1	27.6	.00008
Above Colusa Basin Drain	113	90.5	1.7	.00007
Below Knights Landing	114	88.8	7.3	.00007
Above Sacramento Slough	117	81.5	18.9	.00007
Bryte	124	62.6	9.4	.00001**
Clay Bank Bend	130	53.2	6.8	.00001**
Freeport Bridge	140	46.4	3.0	.00001**
Above Clarksburg	144	43.4	6.2	.00001**
Snodgrass Slough	150	37.2		

* Keswick Dam located in this reach.

** Slopes of water surface from vicinity of Sacramento downstream are dependent upon tidal activity.

TABLE I.5

SACRAMENTO RIVER WATER POLLUTION SURVEY

HYDRAULIC CHARACTERISTICS OF SACRAMENTO RIVER

KESWICK TO SACRAMENTO

1960-1961

			2000 cfs							4000 cfs							6000 cfs						
Cross Section No	River Mileage	Length of Reach (Feet)	Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Cross Sectional Area (Sq Ft)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time
1	300.68		1333	108	12.3	11.3		1.50		2105	114	18.5	15.5		1.90		2609	116	22.5	17.7		2.30	
		3200					0.45		0.7					0.51		0.6					0.52		0.
2	300.07		2000	200	10.0	9.8		1.00		3333	238	13.9	13.6		1.20		3750	245	15.3	14.9		1.60	
		6650					1.22		1.5					1.43		1.2					1.47		0.
3	298.81		1430	210	6.8	6.2		1.40		2222	244	9.1	8.9		1.80		2500	250	10.0	9.7		2.40	
		4300					1.57		1.1					1.68		0.8					1.71		0.
4	298.00		2500	447	5.6	5.6		0.80		3922	460	8.5	8.5		1.02		4110	461	8.9	8.9		1.46	
		1750					0.85		0.6					0.88		0.2					0.89		0.
5	297.67		2680	506	5.3	5.3		0.75		4082	532	7.7	7.6		0.98		4286	535	8.0	8.0		1.40	
		6400					0.33		1.8					0.34		1.4					0.34		1.
6	296.46)		1695	404	4.2	4.2		1.18		2632	414	6.4	6.3		1.52		3061	418	7.3	7.2		1.96	
	)																						
7	295.72)																						
	)	7550					0.36		1.5					0.38		1.2					0.39		1.
8	295.03)		1299	372	3.5	3.5		1.54		2151	400	5.4	5.3		1.86		2609	416	6.3	6.2		2.30	
		5850					1.31		1.0					1.48		0.8					1.54		0.
9	293.92		1220	294	4.1	4.1		1.64		1835	355	5.2	5.1		2.18		2273	369	6.2	6.1		2.64	
		3900					1.28		0.9					1.43		0.6					1.46		0.
10	293.18		2381	480	5.0	4.9		0.84		3226	509	6.3	6.3		1.24		3409	513	6.6	6.6		1.76	
		3750					1.30		0.6					1.52		0.4					1.63		0.
11	292.47		769	162	4.7	4.7		2.60		1136	238	4.8	4.8		3.52		1449	286	5.1	5.0		4.14	
		3400					0.71		0.4					1.03		0.3					1.22		0.
12	291.83		1149	226	5.1	5.1		1.74		1826	326	5.6	5.6		2.19		2381	380	6.3	6.2		2.52	
		5600					1.18		1.4					1.38		1.0					1.47		0.
13	290.77		4260	413	10.3	10.3		0.47		4878	421	11.6	11.5		0.82		5042	424	11.9	11.8		1.19	
		6400					2.20		1.7					2.24		1.2					2.26		0.
14	289.56		1274	426	3.0	3.0		1.57		1802	431	4.2	4.2		2.22		2299	435	5.3	5.2		2.61	
		8400					2.53		1.2					3.26		0.9					3.44		0.
15	287.97		837	268	3.1	3.1		2.39		1290	462	2.8	2.8		3.10		1714	510	3.4	3.3		3.50	
		11200					2.38		1.3					3.41		1.1					3.80		0.
16	285.85		840	297	2.8	2.8		2.38		1325	350	3.8	3.8		3.02		1786	394	4.5	4.5		3.36	
		8150					3.01		1.0					3.36		0.7					3.64		0.
17	284.31		847	316	2.7	2.7		2.36		1274	333	3.8	3.8		3.14		1667	347	4.8	4.8		3.60	
		6900					1.36		0.9					1.54		0.7					1.59		0.
18	283.00		1170	426	2.7	2.7		1.11		1754	505	3.5	3.5		2.28		2273	518	4.4	4.4		2.64	
		9750					2.62		1.8					3.20		1.3					3.37		1.
19	281.15		1504	192	7.8	7.8		1.33		2174	250	8.6	8.6		1.84		2778	277	10.0	9.9		2.16	
		7900					2.82		1.4					3.22		1.0					3.40		0.
20	279.65		1053	318	3.3	3.3		1.90		1538	332	4.6	4.6		2.60		1840	339	5.4	5.4		3.26	
		8700					2.75		1.0					2.96		1.1					3.10		0.
21	278.00		730	327	2.2	2.2		2.74		1047	362	2.9	2.9		3.82		1376	388	3.5	3.5		4.36	
		16450					5.23		2.6					5.53		1.8					5.74		1.
22	274.88		2500	411	6.1	6.0		0.80		3077	418	7.4	7.3		1.30		3529	423	8.3	8.3		1.70	
		9400					3.34		1.7					3.76		1.2					3.84		0.
23	273.10		862	266	3.2	3.2		2.32		1242	342	3.6	3.6		3.22		1500	353	4.2	4.2		4.00	
		8800					2.52		1.2					2.98		0.8					3.04		0.
24	271.43		1031	274	3.8	3.8		1.94		1550	289	5.4	5.3		2.58		2041	294	6.9	6.8		2.94	
		10100					2.52		1.6					2.78		1.2					2.83		1.
25	269.52		1333	318	4.2	4.2		1.50		2073	364	5.7	5.6		1.93		2655	370	7.2	7.1		2.26	
		11600					5.08		1.6					5.57		1.3					5.74		1.
26	267.32		800	353	2.3	2.3		2.50		1250	370	3.4	3.4		3.20		1604	387	4.1	4.1		3.74	
		9500					2.56		1.3					2.68		1.0					2.78		1.
27	265.52		1351	337	4.0	4.0		1.48		2020	351	5.8	5.7		1.98		2553	363	7.0	7.0		2.35	
		11900					2.88		2.4					2.98		1.8					3.06		1.
28	263.27		1639	350	4.7	4.6		1.22		2326	359	6.5	6.4		1.72		2885	367	7.9	7.7		2.08	
		6750					1.88		1.4					1.95		1.0					2.01		0.
29	261.99		1325	279	4.7	4.7		1.51		1914	292	6.6	6.4		2.09		2410	303	8.0	7.8		2.49	
		11750					2.49		2.2					2.58		1.5					2.66		1.
30	259.76		1333	407	3.3	3.3		1.50		1852	419	4.4	4.4		2.16		2273	429	5.3	5.3		2.64	
		3100					0.82		0.4					0.85		0.3					0.88		0.
31	259.17		806	287	2.8	2.8		2.48		1156	306	3.8	3.8		3.46		1471	321	4.6	4.6		4.08	
		8800					1.70		1.3					1.82		0.9					1.92		0.
32	257.50		1449	204	7.1	7.0		1.38		2105	223	9.4	9.2		1.90		2586	236	11.0	10.7		2.32	
		6200					1.92		1.1					2.04		0.8					2.16		0.
33	256.33)		1176	310	3.8	3.8		1.70		1724	324	5.3	5.3		2.32		2190	343	6.4	6.3		2.74	
	)																						
34	254.68)																						
	)	24700					5.26		5.0					5.51		3.5					5.69		2.
35	253.31)																						
	)																						
36	251.65)		1923	304	6.3	6.1		1.04		2500	318	7.9	7.6		1.60		2941	320	9.2	8.8		2.04	
		3550					0.92		0.5					0.94		0.7					0.95		0.
37	250.98		2564	277	9.3	9.0		0.78		2985	279	10.7	10.3		1.34		3488	282	12.4	11.8		1.72	
		10250					3.29		3.2					3.3		1.9					3.34		1.
38	249.04		2000	507	3.9	3.9		1.00		2353	510	4.6	4.6		1.70		2727	513	5.3	5.3		2.20	
		11400					4.48		2.3					5.15		1.5					5.29		1.
39	246.88		1149	353	3.3	3.2		1.74		1550	416	3.7	3.7		2.58		1899	438	4.3	4.3		3.16	
		3650					1.11		0.7					1.26		0.5					1.33		0.
40	246.19		1786	215	8.3	8.2		1.12		2222	234	9.5	9.3		1.80		2632	242	10.9	10.6		2.28	
		10800					3.39		2.3					3.53		1.5					3.58		1.
41	244.14		1399	396	3.5	3.5		1.43		1887	401	4.7	4.7		2.12		2299	404	5.7	5.7		2.61	
		11400					3.92		1.9					4.05		1.3					4.15		1.
42	241.98		1020	377	2.7	2.7		1.96		1515	396	3.8	3.8		2.64		1911	412	4.6	4.6		3.14	
		9700					5.16		1.3					5.31		1.0					5.43		0.
43	240.14		905	749	1.2	1.2		2.21		1384	764	1.8	1.8		2.89		1786	772	2.3	2.3		3.36	

TABLE 1.5

SACRAMENTO RIVER WATER POLLUTION SURVEY

HYDRAULIC CHARACTERISTICS OF SACRAMENTO RIVER

KESWICK TO SACRAMENTO

1960–1961

		8000 cfs							10,000 cfs							25,000 cfs							
River Mileage	Length of Reach (Feet)	Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Cross Sectional Area (Sq Ft)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Cross Section No
300.68		2963	116	25.5	19.5		2.70		3226	116	27.8	20.7		3.10		4545	144	31.6	23.8		5.50		1
	3200					0.55		0.4					0.57		0.3					0.64		0.2	
300.07		4444	259	17.2	16.7		1.80		5000	274	18.2	17.7		2.00		5435	294	18.5	18.0		4.60		2
	6650					1.54		0.8					1.61		0.7					1.98		0.4	
298.81		2857	260	11.0	10.7		2.80		3030	266	11.4	11.1		3.30		4717	374	12.6	12.3		5.30		3
	4300					1.73		0.5					1.74		0.4					2.01		0.2	
298.00		4255	462	9.2	9.7		1.88		4525	463	9.8	9.7		2.21		5252	468	11.2	11.1		4.76		4
	1750					0.89		0.3					0.89		0.2					0.91		0.1	
297.67		4396	537	8.2	8.1		1.82		4630	541	8.6	8.5		2.16		5556	550	10.1	10.0		4.50		5
	6400					0.34		0.8					0.35		0.7					0.36		0.4	
296.46)		3333	420	7.9	7.8		2.40		3704	425	8.7	8.6		2.70		6127	468	13.1	12.8		4.08		6
)																							
295.72)																							7
)	7550					0.40		0.8					0.40		0.7					0.48		0.5	
295.03)		2941	426	6.9	6.8		2.72		3401	437	7.8	7.7		2.94		5841	554	10.5	10.4		4.28		8
	5850					1.58		0.6					1.63		0.5					2.19		0.4	
293.92		2649	380	7.0	6.9		3.02		3030	392	7.7	7.7		3.30		5981	561	10.7	10.5		4.18		9
	3900					1.48		0.4					1.52		0.4					1.89		0.3	
293.18		3636	516	7.0	7.0		2.20		4167	526	7.9	7.9		2.40		7669	578	13.3	13.1		3.26		10
	3750					1.70		0.3					1.76		0.3					2.12		0.2	
292.47		1878	321	5.9	5.8		4.26		2174	340	6.4	6.3		4.60		4281	464	9.2	9.2		5.84		11
	3400					1.42		0.3					1.48		0.2					1.73		0.2	
291.83		2899	452	6.4	6.4		2.76		3106	468	6.6	6.6		3.22		5155	482	10.7	10.6		4.85		12
	5600					1.62		0.7					1.66		0.6					1.72		0.4	
290.77		5229	425	12.3	12.2		1.53		5405	428	12.6	12.5		1.85		7353	448	16.4	16.3		3.40		13
	6400					2.27		0.8					2.28		0.7					2.42		0.4	
289.56		2667	438	6.1	6.0		3.00		2924	440	6.6	6.6		3.42		5144	473	10.9	10.7		4.86		14
	8400					3.48		0.7					3.52		0.6					3.73		0.4	
287.97		2030	518	3.9	3.9		3.94		2326	523	4.4	4.4		4.30		4274	547	7.8	7.7		5.85		15
	11200					3.84		0.8					3.86		0.7					4.28		0.5	
285.85		2128	395	5.4	5.3		3.76		2381	397	6.0	6.0		4.20		4195	474	8.9	8.7		5.96		16
	8150					3.68		0.6					3.72		0.5					4.19		0.4	
284.31		1961	353	5.6	5.5		4.08		2160	358	6.0	6.0		4.63		4139	377	11.0	10.8		6.04		17
	6900					1.62		0.5					1.64		0.5					1.74		0.3	
283.00		2597	528	4.9	4.9		3.08		2841	535	5.3	5.3		3.52		4690	566	8.3	8.2		5.33		18
	9750					3.46		0.9					3.54		0.8					3.89		0.6	
281.15		3113	290	10.7	10.6		2.57		3333	300	11.1	10.9		3.00		5760	355	16.2	15.9		4.34		19
	7900					3.49		0.7					3.56		0.6					4.06		0.5	
279.65		2162	342	6.3	6.2		3.70		2439	345	7.1	7.0		4.10		5470	379	14.4	14.0		4.58		20
	8700					3.19		0.6					3.28		0.5					3.77		0.5	
278.00		1626	406	4.0	4.0		4.92		1852	428	4.3	4.3		5.40		4195	506	8.3	8.2		5.96		21
	16450					5.89		1.3					6.05		1.2					6.70		0.9	
274.88		3810	427	8.9	8.9		2.10		4000	429	9.3	9.3		2.50		5952	443	13.4	13.3		4.20		22
	9400					3.90		0.8					3.94		0.6					4.10		0.5	
273.10		1667	362	4.6	4.6		4.80		1767	367	4.8	4.8		5.66		3676	385	9.5	9.4		6.80		23
	8800					3.11		0.6					3.14		0.5					3.59		0.4	
271.43		2410	297	8.1	8.0		3.32		2618	300	8.7	8.6		3.82		4883	380	12.9	12.7		5.12		24
	10100					2.86		1.0					2.88		0.8					3.51		0.6	
269.52		3101	375	8.3	8.2		2.58		3289	377	8.7	8.6		3.04		5869	449	13.1	12.9		4.26		25
	11600					5.80		0.9					5.83		0.8					6.80		0.6	
267.32		1860	389	4.8	4.7		4.30		1938	390	5.0	4.9		5.16		4045	445	9.1	9.0		6.18		26
	9500					2.82		0.8					2.85		0.6					3.35		0.5	
265.52		2963	372	8.0	7.9		2.70		3125	377	8.3	8.2		3.20		6039	460	13.1	13.0		4.14		27
	11900					3.10		1.2					3.13		1.0					3.66		0.9	
263.27		3030	370	8.2	8.0		2.64		3165	371	8.5	8.3		3.16		7184	415	17.3	16.7		3.48		28
	6750					2.06		0.7					2.06		0.6					2.40		0.5	
261.99		3030	316	9.6	9.4		2.64		3226	320	10.1	9.8		3.10		6849	398	17.7	17.1		3.65		29
	11750					2.73		1.1					2.76		1.0					3.04		0.8	
259.76		2614	436	6.0	6.0		3.06		2703	442	6.1	6.1		3.70		5388	454	11.9	11.7		4.64		30
	3100					0.90		0.2					0.92		0.2					1.06		0.2	
259.17		1660	330	5.0	5.0		4.82		1742	336	5.2	5.2		5.74		3882	446	8.7	8.6		6.44		31
	8800					1.99		0.7					2.02		0.6					2.77		0.4	
257.50		3077	245	12.6	12.2		2.60		3247	249	13.0	12.7		3.08		5274	358	14.7	14.3		4.74		32
	6200					2.22		0.6					2.25		0.5					3.16		0.4	
256.33)		2581	349	7.4	7.3		3.10		2809	354	7.9	7.9		3.56		5507	489	11.3	11.1		4.54		33
)																							
254.68)																							34
)	24700					5.78		2.5					5.81		2.1					7.05		1.5	
253.31)																							35
)																							
251.65)		3306	322	10.3	9.8		2.42		3472	323	10.7	10.2		2.88		5631	332	17.0	15.8		4.44		36
	3550					0.96		0.4					0.96		0.4					1.16		0.2	
250.98		3922	284	13.8	13.2		2.04		4065	286	14.2	13.6		2.46		6983	404	17.3	16.5		3.58		37
	10250					3.37		1.2					3.38		1.0					3.94		0.7	
249.04		3077	516	6.0	5.9		2.60		3333	517	6.4	6.4		3.00		5556	533	10.4	10.3		4.50		38
	11400					5.47		1.0					5.51		0.9					5.74		0.6	
246.88		2222	470	4.7	4.7		3.60		2500	476	5.3	5.2		4.00		4699	498	9.4	9.3		5.32		39
	3650					1.40		0.3					1.44		0.3					1.61		0.2	
246.19		3077	250	12.3	11.9		2.60		3333	259	12.9	12.4		3.00		6127	325	18.9	18.2		4.08		40
	10800					3.67		1.1					3.70		0.9					4.26		0.7	
244.14		2703	408	6.6	6.6		2.96		2985	410	7.3	7.2		3.35		5600	443	12.6	12.5		4.46		41
	11400					4.24		1.0					4.30		0.9					4.55		0.7	
241.98		2285	426	5.4	5.3		3.50		2545	434	5.9	5.8		3.93		4970	454	10.9	10.8		5.03		42
	9700					5.52		0.7					5.58		0.7					5.75		0.5	
240.14		2151	777	2.8	2.8		3.72		2415	781	3.1	3.1		4.14		4771	800	6.0	5.9		5.24		43

TABLE 15

SACRAMENTO RIVER WATER POLLUTION SURVEY

HYDRAULIC CHARACTERISTICS OF SACRAMENTO RIVER

KESWICK TO SACRAMENTO

1960-1961

Cross Section No	River Mileage	Length of Reach (Feet)	2000 cfs							4000 cfs							6000 cfs						
			Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Cross Sectional Area (Sq Ft)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time
43	240.14		905	749	1.2	1.2		2.21		1384	764	1.8	1.8		2.89		1786	772	2.3	2.3		3.36	
		16950					6.94		2.3					7.55		1.8					7.89		1
44	236.93)		1099	256	4.3	4.2		1.82		1626	330	4.9	4.8		2.46		2113	372	5.7	5.5		2.84	
	)																						
45	235.58)																						
	)	13600					3.88		2.2					5.10		1.6					5.96		1
46	234.35)		1220	255	4.8	4.7		1.64		1754	342	5.1	5.0		2.28		2222	414	5.4	5.3		2.70	
		13850					2.59		2.1					4.55		1.5					5.22		1
47	231.73		1000	378	2.6	2.6		2.00		1449	414	3.5	3.5		2.76		1887	452	4.2	4.2		3.18	
		5500					2.17		0.7					2.47		0.5					2.81		0
48	230.69		885	222	4.0	4.0		2.26		1311	270	4.9	4.8		3.05		1729	326	5.3	5.3		3.41	
		4700					1.46		0.8					1.63		0.6					1.82		0
49	229.80		2247	339	6.6	6.6		0.89		2740	353	7.8	7.7		1.46		3390	369	9.2	9.1		1.77	
		7500					3.01		1.8					3.10		1.2					3.18		1
50	228.38		1449	580	2.5	2.5		1.38		2041	596	3.4	3.4		1.96		2586	603	4.3	4.3		2.32	
		5200					2.13		1.1					2.22		0.8					2.31		0
51	227.40		1471	379	3.9	3.9		1.36		2174	399	5.4	5.4		1.84		2804	416	6.7	6.7		2.14	
		2500					0.89		0.5					1.08		0.3					1.23		0
52	226.93		1282	300	4.3	4.3		1.56		1786	430	4.2	4.1		2.24		2256	528	4.3	4.3		2.66	
		1550					0.65		0.2					0.88		0.2					1.07		0
53	226.64		1399	210	6.7	6.6		1.43		2073	258	8.0	8.0		1.93		2655	291	9.1	9.1		2.26	
		6100					1.57		1.1					1.77		0.9					1.91		0
54	225.48		1299	315	4.1	4.1		1.54		1970	331	6.0	5.9		2.03		2532	345	7.3	7.3		2.37	
		5950					1.69		0.8					1.86		0.6					2.06		0
55	224.35		685	236	2.9	2.9		2.92		1013	278	3.6	3.6		3.95		1354	328	4.1	4.1		4.43	
		8200					2.76		1.0					3.01		0.8					3.26		0
56	222.80		1429	468	3.1	3.0		1.40		2020	488	4.1	4.1		1.98		2521	503	5.0	5.0		2.38	
		8500					2.87		1.5					3.04		1.2					3.16		1
57	221.19		1220	245	5.0	4.9		1.64		1905	266	7.2	7.1		2.10		2400	280	8.6	8.5		2.50	
		10550					3.54		1.4					4.20		1.1					4.59		0
58	219.19		781	228	3.4	3.4		2.56		1190	295	4.0	4.0		3.36		1567	332	4.7	4.7		3.83	
		8050					1.90		1.0					2.53		0.9					2.84		0
59	217.67		1563	215	7.3	7.2		1.28		2198	286	7.7	7.7		1.82		2679	332	8.1	8.0		2.24	
		11650					4.04		2.3					5.05		1.3					5.71		1
60	215.46		800	300	2.7	2.7		2.50		1212	355	3.4	3.4		3.30		1648	398	4.1	4.1		3.64	
		22900					7.90		3.3					9.06		2.6					10.03		2
61	211.12		1481	317	4.7	4.7		1.35		2260	352	6.4	6.4		1.77		2927	382	7.7	7.6		2.05	
		11550					4.00		2.4					4.64		1.8					4.90		1
62	208.93		1481	605	2.4	2.4		1.35		2186	716	3.1	3.0		1.83		2804	747	3.8	3.7		2.14	
		13500					5.96		4.0					6.76		2.7					7.21		2
63	206.37		3846	287	13.4	13.0		0.52		4082	297	13.7	13.3		0.98		4615	330	14.0	13.5		1.30	
		8350					4.27		3.4					4.47		1.9					4.82		1
64	204.79		2326	403	5.8	5.7		0.86		2857	423	6.8	6.7		1.40		3409	445	7.7	7.6		1.76	
		14300					7.15		4.8					7.34		3.1					7.58		2
65	202.08		3226	423	7.6	7.6		0.62		3509	426	8.2	8.2		1.14		3947	430	9.2	9.1		1.52	
		6100					3.10		2.7					3.16		1.5					3.18		1
66	200.92		2941	435	6.8	6.7		0.68		3810	445	8.6	8.5		1.05		4225	450	9.4	9.3		1.42	
		7250					3.64		3.0					3.70		1.6					3.73		1
67	199.55		2273	601	3.8	3.8		0.88		2632	605	4.4	4.3		1.52		3000	609	4.9	4.9		2.00	
		12550					3.00		4.0					3.26		2.4					3.34		1
68	197.17		2222	445	5.0	5.0		0.90		2899	532	5.4	5.4		1.38		3352	556	6.0	6.0		1.79	
		12500					4.00		2.2					4.61		1.6					4.90		1
69	194.80		862	326	2.6	2.6		2.32		1290	358	3.6	3.6		3.10		1685	388	4.3	4.3		3.56	
		12850					5.21		1.8					5.57		1.3					5.89		1
70	192.37		1176	363	3.2	3.2		1.70		1802	378	4.8	4.7		2.22		2326	390	6.0	5.9		2.58	
		6700					3.44		0.4					3.98		0.9					4.37		0
71	191.10		1408	476	3.0	2.9		1.42		2128	592	3.6	3.6		1.88		2765	674	4.1	4.1		2.17	
		21550					10.17		6.7					11.03		4.6					11.65		3
72	187.02		5556	894	6.2	6.2		0.36		5714	896	6.4	6.4		0.70		6122	897	6.8	6.8		0.98	
		7100					3.24		3.3					3.30		1.9					3.37		1
73	185.68		2273	438	5.2	5.2		0.88		2941	465	6.3	6.3		1.36		3659	493	7.4	7.4		1.64	
		5600					2.14		1.8					2.25		0.8					2.35		1
74	184.62		1075	472	2.3	2.3		1.86		1633	491	3.3	3.3		2.45		2182	510	4.3	4.3		2.75	
		14300					5.43		3.0					5.75		2.1					6.010		1
75	181.91		2439	331	7.4	7.3		0.82		2963	360	8.2	8.1		1.35		3659	395	9.3	9.1		1.64	
		13200					4.70		5.2					5.04		3.1					5.36		2
76	179.41		3509	397	8.8	8.8		0.57		3922	414	9.5	9.4		1.02		4545	436	10.4	10.4		1.32	
		8450					2.82		1.6					3.30		1.2					3.53		1
77	177.81		877	350	2.5	2.5		2.28		1389	462	3.0	3.0		2.88		1840	500	3.7	3.7		3.26	
		9550					3.09		1.5					4.06		1.1					4.44		1
78	176.00		1550	288	5.4	5.3		1.29		2162	376	5.8	5.7		1.85		2703	417	6.5	6.4		2.22	
		11150					3.31		2.1					4.71		1.5					5.01		1
79	173.89		1190	352	3.4	3.4		1.68		1724	533	3.2	3.2		2.32		2222	549	4.0	4.0		2.70	
		6800					2.31		1.5					2.80		1.0					2.88		0
80	172.60		2469	546	4.5	4.5		0.81		2740	554	4.9	4.9		1.46		3243	567	5.7	5.7		1.85	
		13000					4.04		3.2					4.46		2.0					5.02		1
81	170.14		1361	400	3.4	3.4		1.47		1869	488	3.8	3.8		2.14		2362	606	3.9	3.9		2.54	
		9800					2.98		2.6					3.35		1.7					3.84		1
82	168.28		3333	352	9.5	9.4		0.60		3636	358	10.2	10.0		1.10		4000	364	11.0	10.8		1.50	
		8300					3.04		1.4					3.33		1.0					3.64		0
83	166.71		746	169	4.4	4.3		2.68		1096	212	5.2	5.0		3.65		1446	259	5.6	5.5		4.15	
		13050					3.46		2.1					3.90		1.4					4.18		1
84	164.24		2469	338	7.3	7.2		0.81		2703	340	8.0	7.8		1.48		3226	343	9.4	9.2		1.86	
		14450					5.90		5.5					5.92		3.0					5.96		2
85	161.50		3125	269	11.6	11.1		0.64		3333	270	12.3	11.7		1.20		3409	271	12.6	12.0		1.76	

TABLE 1.5

SACRAMENTO RIVER WATER POLLUTION SURVEY

HYDRAULIC CHARACTERISTICS OF SACRAMENTO RIVER

KESWICK TO SACRAMENTO

1960–1961

		8000 cfs							10,000 cfs							25,000 cfs							
River Mileage	Length of Reach (Feet)	Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Cross Section No
240.14		2151	777	2.8	2.8		3.72		2415	781	3.1	3.1		4.14		4771	800	6.0	5.9		5.24		43
	16950					8.21		1.4					8.42		1.2					11.61		1.0	
236.93)		2484	413	6.0	5.9		3.22		2762	440	6.3	6.1		3.62		5411	882	6.1	6.1		4.62		44
)																							
235.58)																							45
)	13600					6.76		1.2					7.03		1.1					10.80		0.8	
234.35		2632	478	5.5	5.4		3.04		2950	487	6.1	5.9		3.39		5631	541	10.4	10.2		4.44		46
	13850					5.67		1.2					5.78		1.1					6.54		0.8	
231.73		2286	464	4.9	4.9		3.50		2604	475	5.5	5.5		3.84		5342	546	9.8	9.6		4.68		47
	5500					3.04		0.4					3.32		0.4					3.82		0.3	
230.69		2089	377	5.5	5.5		3.83		2481	440	5.6	5.6		4.03		4941	511	9.7	9.6		5.06		48
	4700					1.98		0.4					2.19		0.4					2.53		0.3	
229.80		3810	381	10.0	9.9		2.10		4310	395	10.9	10.9		2.32		7022	456	15.4	15.1		3.56		49
	7500					3.27		0.9					3.34		0.8					3.65		0.6	
228.38		3030	620	4.9	4.9		2.64		3378	630	5.4	5.3		2.96		6378	660	9.7	9.6		3.92		50
	5200					2.33		0.6					2.38		0.5					2.56		0.4	
227.40		3306	428	7.7	7.6		2.42		3788	437	8.7	8.5		2.64		6831	491	13.9	13.7		3.66		51
	2500					1.29		0.3					1.32		0.2					1.55		0.2	
226.93		2632	560	4.7	4.7		3.04		2857	574	5.0	4.9		3.50		5631	697	8.1	8.0		4.44		52
	1550					1.11		0.2					1.15		0.1					1.42		0.1	
226.64		3226	313	10.3	10.2		2.48		3676	331	11.1	11.0		2.72		7062	414	17.1	16.7		3.54		53
	6100					2.01		0.7					2.09		0.6					2.37		0.5	
225.48		3042	357	8.5	8.5		2.63		3356	364	9.2	9.2		2.98		6527	373	17.5	16.7		3.83		54
	5950					2.18		0.4					2.30		0.4					2.66		0.3	
224.35		1610	356	4.5	4.5		4.97		1873	390	4.8	4.8		5.34		4209	498	8.5	8.4		5.94		55
	8200					3.44		0.6					3.60		0.5					4.13		0.5	
222.80		3053	518	5.9	5.8		2.62		3311	527	6.3	6.2		3.02		6757	554	12.2	12.0		3.70		56
	8500					3.26		0.9					3.32		0.8					3.50		0.6	
221.19		2857	288	9.9	9.8		2.80		3279	294	11.2	11.0		3.05		6460	315	20.5	19.8		3.87		57
	10550					4.92		0.8					5.16		0.8					7.67		0.6	
219.19		1878	369	5.1	5.0		4.26		2119	393	5.4	5.3		4.72		4673	708	6.6	6.4		5.35		58
	8050					3.14		0.7					3.38		0.6					5.00		0.5	
217.67		3077	364	8.5	8.4		2.60		3521	397	8.9	8.8		2.84		6281	462	13.6	13.3		3.98		59
	11650					6.15		1.0					6.68		0.9					7.86		0.7	
215.46		1946	420	4.6	4.6		4.11		2278	455	5.0	5.0		4.39		4209	541	7.8	7.7		5.94		60
	22900					10.54		2.0					11.28		1.8					13.74		1.3	
211.12		3419	399	8.6	8.6		2.34		3937	424	9.3	9.2		2.54		6313	530	11.9	11.8		3.96		61
	11550					5.02		1.3					5.14		1.2					5.88		0.8	
208.93		3292	753	4.4	4.4		2.43		3759	759	5.0	4.9		2.66		6219	825	7.5	7.5		4.02		62
	13500					7.50		1.9					7.72		1.7					8.65		1.0	
206.37		5128	367	14.0	13.5		1.56		5525	396	14.0	13.5		1.81		7911	469	16.9	16.2		3.16		63
	8350					5.15		1.3					5.44		1.1					6.14		0.7	
204.79		3902	463	8.4	8.3		2.05		4405	480	9.2	9.0		2.27		6944	523	13.3	13.1		3.60		64
	14300					7.78		2.1					7.98		1.8					8.62		1.1	
202.08		4545	435	10.4	10.4		1.76		4950	442	11.2	11.1		2.02		7102	473	15.0	14.8		3.52		65
	6100					3.22		1.0					3.26		0.9					3.42		0.5	
200.92		4624	455	10.2	10.1		1.73		5208	458	11.4	11.3		1.92		7143	471	15.2	14.9		3.50		66
	7250					3.75		1.0					3.78		0.9					3.86		0.5	
199.55		3419	614	5.6	5.6		2.34		3788	616	6.1	6.1		2.64		6281	627	10.0	9.9		3.98		67
	12550					3.40		1.6					3.41		1.4					3.46		0.9	
197.17		3846	571	6.7	6.7		2.08		4167	573	7.3	7.2		2.40		6831	580	11.8	11.5		3.66		68
	12500					5.10		1.2					5.31		1.0					6.25		0.8	
194.80		2010	411	4.9	4.9		3.98		2242	450	5.0	5.0		4.46		4480	623	7.2	7.2		5.58		69
	12850					6.14		1.0					6.45		0.9					8.00		0.7	
192.37		2740	400	6.9	6.8		2.92		3000	403	7.4	7.4		3.33		5342	435	12.3	12.1		4.68		70
	6700					4.54		0.7					4.61		0.6					4.81		0.4	
191.10		3306	716	4.6	4.6		2.42		3636	719	5.1	5.0		2.75		5952	738	8.1	8.0		4.20		71
	21550					11.95		3.2					11.99		2.7					12.21		1.8	
187.02		6154	898	6.9	6.8		1.30		6173	899	6.9	6.8		1.62		10593	908	11.7	11.6		2.36		72
	7100					3.41		1.2					3.41		1.0					3.49		0.7	
185.68		4124	511	8.1	8.0		1.94		4386	512	8.6	8.5		2.28		8278	528	15.7	15.5		3.02		73
	5600					2.44		0.6					2.60		0.6					3.67		0.5	
184.62		2632	526	5.0	5.0		3.04		3058	554	5.5	5.5		3.27		6649	782	8.5	8.5		3.76		74
	14300					6.39		1.6					6.60		1.4					8.32		1.2	
181.91		4103	421	9.7	9.6		1.95		4444	425	10.5	10.3		2.25		8418	452	18.6	18.1		2.97		75
	13200					5.63		2.0					5.63		1.7					6.26		1.3	
179.41		4908	451	10.9	10.7		1.63		5076	454	11.2	11.1		1.97		8803	519	17.0	16.6		2.84		76
	8450					3.62		0.9					3.70		0.8					4.54		0.6	
177.81		2133	510	4.2	4.2		3.75		2451	528	4.6	4.6		4.08		5376	687	7.8	7.8		4.65		77
	9550					4.70		0.9					4.81		0.8					6.00		0.6	
176.00		3200	459	7.0	7.0		2.50		3521	465	7.6	7.5		2.84		6906	551	12.5	12.3		3.62		78
	11150					5.30		1.1					5.33		1.0					6.58		0.8	
173.89		2685	562	4.8	4.8		2.98		2967	564	5.3	5.2		3.37		6053	585	10.3	10.3		4.13		79
	6800					2.95		0.7					2.96		0.6					3.11		0.5	
172.60		3810	583	6.5	6.5		2.10		3937	584	6.7	6.7		2.54		7463	625	11.9	11.8		3.35		80
	13000					5.20		1.5					5.29		1.3					5.95		1.0	
170.14		2817	634	4.4	4.4		2.84		3125	654	4.8	4.7		3.20		6172	767	8.0	7.9		4.05		81
	9800					3.98		1.2					4.07		1.0					4.55		0.7	
168.28		4444	372	11.9	11.8		1.80		4587	373	12.3	12.1		2.18		6250	381	16.4	16.0		4.00		82
	8300					3.84		0.7					3.90		0.6					4.44		0.5	
166.71		1720	286	6.0	5.9		4.65		2000	296	6.8	6.6		5.00		4045	379	10.7	10.5		6.18		83
	13050					4.32		1.1					4.40		1.0					5.07		0.7	
164.24		3704	346	10.7	10.4		2.16		3906	347	11.3	10.9		2.56		7062	363	19.5	18.6		3.54		84
	14450					6.02		1.9					6.03		1.6					6.52		1.2	
161.50		3960	274	14.5	13.7		2.02		4132	275	15.0	14.2		2.42		7310	309	23.7	22.0		3.42		85

TABLE 15

SACRAMENTO RIVER WATER POLLUTION SURVEY

HYDRAULIC CHARACTERISTICS OF SACRAMENTO RIVER

KESWICK TO SACRAMENTO

1960–1961

Cross Section No	River Mileage	Length of Reach (Feet)	2000 cfs Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	4000 cfs Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	6000 cfs Cross Sectional Area (Sq Ft)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time
85	161.50		3125	269	11.6	11.1		0.64		3333	270	12.3	11.7		1.20		3409	271	12.6	12.0		1.76	
		17600					6.48		6.4					6.53		3.4					6.63		
86	158.17)		2273	220	10.3	10.1		0.88		2353	222	10.6	10.3		1.70		2586	228	11.3	11.0		2.32	
	)	22550					7.37		6.9					7.44		3.6					7.57		
87	156.86)																						
	)																						
88	153.90)		2128	213	10.0	9.7		0.94		2286	215	10.6	10.3		1.75		2362	215	11.0	10.6		2.54	
		7750					2.51		2.6					2.55		1.5					2.57		
89	152.43		2857	245	11.7	11.5		0.70		3306	250	13.2	13.0		1.21		3571	253	14.1	13.8		1.68	
		19900					6.65		6.4					6.96		3.9					7.24		
90	148.66		1923	239	8.0	7.9		1.04		2516	257	9.8	9.6		1.59		3046	274	11.1	10.9		1.97	
		12300					3.64		2.4					3.92		1.7					4.13		
91	146.33		1099	168	6.5	6.1		1.82		1688	183	9.2	8.6		2.37		2158	191	11.3	10.5		2.78	
		11850					3.35		2.3					3.92		1.7					4.05		
92	144.09		1942	231	8.4	8.1		1.03		2703	284	9.5	9.2		1.48		3191	294	10.9	10.4		1.88	
		13400					3.79		3.0					4.28		2.0					4.42		
93	141.55		1351	260	5.2	5.1		1.48		1835	270	6.8	6.7		2.18		2290	278	8.2	8.1		2.62	
		13450					4.32		3.1					4.41		1.9					4.54		
94	139.00		2128	342	6.2	6.2		0.94		2326	346	6.7	6.7		1.72		2740	354	7.7	7.7		2.19	
		15350					4.65		4.4					4.71		2.4					4.85		
95	136.09		2000	226	8.8	8.6		1.00		2162	229	9.4	9.2		1.85		2564	237	10.8	10.6		2.34	
		8200					2.41		2.4					2.47		1.3					2.58		
96	134.54		2222	204	10.9	10.5		0.90		2469	211	11.7	11.3		1.62		3000	224	13.4	12.8		2.00	
		21350					6.65		6.2					6.80		3.6					7.09		
97	130.50		2000	274	7.3	7.2		1.00		2326	[illegible]	8.4	8.3		1.72		2830	286	9.9	9.7		2.12	
		14850					4.00		4.0					4.26		2.4					4.41		
98	127.69		1887	196	9.6	9.5		1.06		2260	214	10.6	10.4		1.77		2778	222	12.5	12.2		2.16	
		10200					2.49		2.2					2.71		1.5					2.84		
99	125.76		1361	269	5.1	5.0		1.47		1942	284	6.8	6.8		2.06		2479	297	8.3	8.3		2.42	
		5500					1.24		1.1					1.29		0.8					1.34		
100	124.72		1613	302	5.3	5.1		1.24		2235	312	7.2	7.1		1.79		2844	320	8.9	8.8		2.11	
		16350					[illegible]		[illegible]					3.97		2.6					4.10		
101	[illegible].62		1770	211	8.4	8.1		1.13		2[illegible]81	224	10.6	10.3		1.68		2970	234	12.7	12.2		2.02	
		11700					3.06		3.0					3.23		2.0					3.35		
102	119.40		1905	226	8.4	8.3		1.05		2469	235	10.5	10.3		1.62		3046	243	12.5	12.2		1.97	
		6800					0.88		1.6					0.92		1.0					0.94		
103	118.11		1538	191	8.1	7.9		1.30		2000	199	10.1	9.8		2.00		2500	206	12.1	11.7		2.40	
		13600					3.17		3.0					3.28		1.9					3.39		
104	115.53		1667	211	7.9	7.7		1.20		2062	216	9.5	9.3		1.94		2586	224	11.5	11.2		2.32	
		19300					3.57		4.7					3.67		2.9					3.80		
105	111.87		1818	221	8.2	8.1		1.10		2286	228	10.0	9.9		1.75		2844	236	12.1	11.8		2.11	
		11350					2.23		2.8					2.31		1.7					2.42		
106	109.72		1754	212	8.3	8.2		1.14		2210	221	10.0	9.9		1.81		2778	233	11.9	11.7		2.16	
		13850					2.46		3.2					2.58		2.0					2.76		
107	107.10		1613	183	8.8	8.8		1.24		2041	196	10.4	10.2		1.96		2620	211	12.4	12.1		2.29	
		23250					3.33		5.2					3.58		3.4					3.86		
108	103.70		1626	221	7.4	7.3		1.23		2139	241	8.9	8.7		1.87		2727	253	10.8	10.6		2.20	
		7350					1.48		1.7					1.57		1.1					1.64		
109	102.31		1695	245	6.9	6.9		1.18		2105	256	8.2	8.2		1.40		2804	267	10.5	10.3		2.14	
		11750					2.55		3.4					2.71		2.1					2.87		
110	100.08		2778	194	14.3	13.7		0.72		3448	211	16.3	15.6		1.16		4082	227	18.0	17.2		1.47	
		20400					3.61		5.8					3.84		3.6					4.08		
111	96.22		1613	208	7.8	7.7		1.24		2020	215	9.4	9.3		1.98		2575	226	11.4	11.1		2.33	
		17850					3.44		3.6					3.70		2.4					3.88		
112	92.84		1258	232	5.4	5.4		1.59		1878	259	7.3	7.1		2.13		2372	269	8.8	8.7		2.53	
		12350					2.08		3.1					2.22		1.3					2.32		
113	90.50		3333	229	14.6	14.1		0.60		3419	231	14.8	14.3		1.17		3509	232	15.1	14.6		1.71	
		2750					0.59		1.0					0.59		0.5					0.61		
114	89.98		2222	258	8.6	8.4		0.90		2424	261	9.3	9.1		1.65		2655	265	10.0	9.8		2.26	
		16400					3.74		5.3					3.80		2.8					3.87		
115	86.87		2410	230	10.5	9.1		0.83		2581	234	11.0	10.8		1.55		2817	238	11.8	11.5		2.13	
		12600					2.72		4.4					2.77		2.3					2.80		
116	84.48		2564	193	13.3	12.4		0.78		2759	197	14.0	13.1		1.45		2857	199	14.4	13.4		2.10	
		17200					3.84		6.2					3.90		3.3					3.96		
117	81.22		2597	211	12.3	11.9		0.77		2740	216	12.7	12.3		1.46		2817	218	12.9	12.5		2.13	
		5300					1.12		1.9					1.16		1.1					1.17		
118	80.22		2632	331	8.0	7.9		0.76		3030	340	8.9	8.8		1.32		3316	345	9.6	9.5		1.81	
		6550					3.27		2.3					3.37		1.3					3.43		
119	78.98		2353	482	4.9	4.9		0.85		2740	497	5.5	5.5		1.46		3030	507	6.0	5.9		1.98	
		18600					7.74		6.2					7.89		3.7					8.02		
120	75.46		2500	512	4.9	4.9		0.80		3030	517	5.9	5.8		1.32		3333	519	6.4	6.4		1.80	
		23450					9.73		8.6					9.88		5.3					9.99		
121	71.02		2778	478	5.8	5.8		0.72		3448	485	7.1	7.1		1.16		3774	489	7.7	7.7		1.59	
		24800					9.75		10.4					10.27		6.6					10.59		
122	66.32		3279	363	9.0	8.9		0.61		4211	396	10.6	10.5		0.95		5172	414	12.5	12.3		1.16	
		14450					6.82		6.3					6.76		4.2					6.97		
123	63.58		2941	454	6.5	6.3		0.68		4167	475	8.8	8.6		0.96		5000	487	10.3	10.0		1.20	
		5700					1.91		2.5					2.06		1.8					2.08		
124	62.50		3448	470	7.3	7.3		0.58		4762	523	9.1	9.1		0.84		5607	557	10.1	10.0		1.07	
		14150					6.72		6.9					7.16		4.7					7.46		
125	59.82		3571	583	6.1	6.1		0.56		4762	598	8.0	7.9		0.84		5714	609	9.4	9.3		1.05	
		3250					1.52		1.6					1.58		1.1					1.62		
126	59.20		3571	463	7.7	7.6		0.56		4762	492	9.7	9.4		0.84		5769	507	11.4	11.0		1.04	

TABLE 1.5

SACRAMENTO RIVER WATER POLLUTION SURVEY

HYDRAULIC CHARACTERISTICS OF SACRAMENTO RIVER

KESWICK TO SACRAMENTO

1960-1961

		8000 cfs							10,000 cfs							25,000 cfs							
River Mileage	Length of Reach (Feet)	Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Cross Sectional Area (Sq Ft)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Cross Section No.
161.50		3960	274	14.5	13.7		2.02		4132	275	15.0	14.2		2.42		7310	309	23.7	22.0		3.42		85
	17600					6.79		2.1					6.83		1.8					7.43		1.3	
158.17)		3077	238	12.9	12.4		2.60		3333	239	13.9	13.3		3.00		6313	251	25.2	22.7		3.96		86
)	22550					7.77		2.2					7.89		2.0					8.61		1.5	
156.86)																							87
153.90)		2685	219	12.3	11.8		2.98		3030	223	13.6	13.1		3.30		5841	253	23.1	21.9		4.28		88
	7750					2.61		0.9					2.64		0.8					2.96		0.6	
152.43		3846	256	15.0	14.7		2.08		4167	259	16.1	15.7		2.40		7310	288	25.4	24.0		3.42		89
	19900					7.46		2.5					7.72		2.2					10.55		1.1	
148.06		3448	289	11.9	11.6		2.32		3745	303	12.4	12.0		2.67		7553	480	15.7	15.2		3.31		90
	12300					4.38		1.3					4.65		1.1					7.23		0.9	
146.33		2581	202	12.8	11.9		3.10		2976	219	13.6	12.7		3.36		6313	333	19.0	17.8		3.96		91
	11850					4.24		1.3					4.41		1.2					5.62		1.0	
144.09		3738	304	12.3	11.8		2.14		4237	308	13.8	13.2		2.36		8446	339	24.9	23.1		2.96		92
	13400					4.58		1.3					4.68		1.4					5.23		1.2	
141.55		2759	285	9.7	9.5		2.90		3289	291	11.3	11.1		3.04		7246	331	21.9	21.1		3.45		93
	13450					4.64		1.4					4.71		1.3					5.22		1.2	
139.00		3252	362	9.0	8.9		2.46		3831	366	10.5	10.3		2.61		8446	396	21.3	20.6		2.96		94
	15350					4.97		1.5					5.05		1.6					5.64		1.4	
136.09		2996	245	12.2	11.9		2.67		3571	251	14.2	13.8		2.80		8117	293	27.7	25.9		3.08		95
	8200					2.69		0.8					2.76		0.9					3.35		0.8	
134.54		3478	234	14.9	14.2		2.30		4065	242	16.8	15.9		2.46		8929	304	29.4	27.2		2.80		96
	21350					7.28		2.5					7.46		2.3					9.01		2.0	
130.50		3361	291	11.5	11.3		2.38		3730	294	12.7	12.4		2.68		8224	345	23.8	22.7		3.04		97
	14850					4.51		1.6					4.57		1.6					5.48		1.3	
127.69		3279	228	14.4	14.0		2.44		3788	235	16.1	15.6		2.64		7962	287	27.7	26.2		3.14		98
	10200					2.90		1.1					2.99		1.0					3.53		0.8	
125.76		2941	305	9.6	9.5		2.72		3401	312	10.9	10.8		2.94		6775	361	18.8	18.3		3.69		99
	5500					1.36		0.7					1.39		0.5					1.54		0.4	
124.72		3347	324	10.3	10.1		2.39		3831	327	11.7	11.4		2.61		7042	350	20.1	19.2		3.55		100
	16350					4.18		2.0					4.26		1.8					4.77		1.3	
121.62		3478	241	14.4	13.8		2.30		3937	249	15.8	15.1		2.54		7246	293	24.7	23.2		3.45		101
	11700					3.45		1.3					3.56		1.3					4.19		1.0	
119.40		3506	250	14.2	13.8		2.25		4032	257	15.7	15.2		2.48		7375	303	24.3	23.3		3.39		102
	6800					0.97		0.7					1.00		0.7					1.15		0.5	
118.11		2963	210	14.1	13.5		2.70		3448	214	16.1	15.2		2.90		6579	241	27.3	24.6		3.80		103
	13600					3.50		1.4					3.62		1.3					4.38		1.0	
115.53		3030	235	12.9	12.5		2.64		3521	247	14.3	13.8		2.84		6944	316	22.0	21.0		3.60		104
	19300					3.94		2.1					4.07		2.0					4.98		1.6	
111.87		3361	241	13.9	13.6		2.38		3876	247	15.7	15.1		2.58		7622	288	26.5	24.9		3.28		105
	11350					2.48		1.3					2.56		1.2					3.08		1.0	
109.72		3279	241	13.6	13.3		2.44		3802	250	15.2	14.8		2.63		7530	307	24.5	23.5		3.32		106
	13850					2.87		1.6					2.98		1.5					3.64		1.2	
107.10		3226	221	14.6	14.2		2.48		3745	230	16.3	15.7		2.67		7440	281	26.5	25.1		3.36		107
	23250					3.96		2.7					4.09		2.5					4.84		2.0	
103.70		3376	260	13.0	12.7		2.37		3906	266	14.7	14.3		2.56		7764	308	25.2	24.0		3.22		108
	7350					1.69		1.0					1.72		0.8					1.99		0.6	
102.31		3390	273	12.4	12.2		2.36		3906	279	14.0	13.7		2.56		8013	320	25.0	23.8		3.12		109
	11750					2.92		1.2					3.00		1.4					3.55		1.1	
100.08		4301	229	18.8	17.8		1.86		4762	237	20.1	19.0		2.10		8834	292	30.3	28.1		2.83		110
	20400					4.20		2.3					4.37		2.2					5.49		1.7	
96.22		2974	237	12.5	12.3		2.69		3413	248	13.8	13.4		2.93		6757	318	21.2	20.5		3.70		111
	17850					4.00		2.0					4.16		1.6					5.13		1.3	
92.84		2694	276	9.8	9.6		2.97		3096	284	10.9	10.7		3.23		6158	337	18.3	17.8		4.06		112
	12350					2.37		1.9					2.43		1.2					2.95		0.9	
90.50		3604	234	15.4	14.8		2.22		3704	236	15.7	15.1		2.70		7353	295	24.9	23.7		3.40		113
	2750					0.62		0.3					0.64		0.3					0.75		0.2	
89.98		3077	270	11.4	11.1		2.60		3497	275	12.7	12.4		2.86		6757	311	21.7	20.8		3.70		114
	16400					3.95		1.9					4.05		1.8					4.66		1.3	
86.87		3279	246	13.3	13.0		2.44		3717	252	14.8	14.2		2.69		7062	298	23.7	21.9		3.54		115
	12600					2.91		1.9					3.02		1.5					3.69		1.0	
84.48		3279	207	15.8	14.8		2.44		3731	216	17.3	16.1		2.68		7062	276	25.6	23.6		3.54		116
	17200					4.09		1.4					4.21		1.8					5.13		1.3	
81.22		3333	224	14.9	14.2		2.40		3760	229	16.4	15.5		2.66		7022	263	26.7	24.0		3.56		117
	5300					1.20		2.1					1.22		0.6					1.39		0.4	
80.22		3704	351	10.6	10.4		2.16		4049	360	11.2	11.1		2.47		7508	405	18.5	18.2		3.33		118
	6550					3.49		0.7					3.56		0.7					3.91		0.5	
78.98		3419	516	6.6	6.6		2.34		3850	523	7.4	7.3		2.60		7267	567	12.8	12.7		3.44		119
	18600					8.09		0.8					8.18		2.1					8.72		1.6	
75.46		3810	522	7.3	7.3		2.10		4219	525	8.0	8.0		2.37		7813	549	14.2	14.1		3.20		120
	23450					10.08		3.3					10.13		2.9					10.67		2.1	
71.02		4420	494	8.9	8.9		1.81		4808	497	9.7	9.6		2.08		8562	524	16.3	16.1		2.92		121
	24800					10.74		4.1					10.81		3.7					11.58		2.5	
66.32		5797	423	13.7	13.5		1.38		6135	426	14.4	14.1		1.63		9615	464	20.7	20.2		2.60		122
	14450					7.13		2.9					7.19		2.4					7.70		1.5	
63.58		5634	497	11.3	11.0		1.42		6024	502	12.0	11.7		1.66		9328	530	17.6	17.1		2.68		123
	5700					2.19		1.2					2.20		1.0					2.30		0.6	
62.50		6250	562	11.1	11.0		1.28		6579	564	11.7	11.6		1.52		9615	584	16.5	16.3		2.60		124
	14150					7.53		3.1					7.57		2.6					7.92		1.5	
59.82		6250	616	10.1	10.1		1.28		6579	620	10.6	10.5		1.52		9615	656	14.7	14.5		2.60		125
	3250					1.65		0.7					1.66		0.6					1.76		0.3	
59.20		6299	515	12.2	11.7		1.27		6623	519	12.8	12.2		1.51		9653	555	17.4	16.0		2.59		126

TABLE I.6

SACRAMENTO RIVER WATER POLLUTION SURVEY

HYDRAULIC CHARACTERISTICS OF SACRAMENTO RIVER

SACRAMENTO TO COLLINSVILLE

For Mean Flow Of 10,000 c.f.s. At Sacramento

1960 - 1961

Cross Section No	River Mileage	Length of Reach (Feet)	Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)	Mean Flow At Section cfs
125	59.82		5,475	709	7.7	7.5				10,000
		18,427					10.83	1.60	3.2	
126	56.33		6,953	466	14.9	12.9				
		6,366					3.40	1.43	1.2	
127	55.13		6,967	607	11.5	10.6				
		3,696					2.18	1.50	0.7	
128	54.43		6,384	570	11.2	10.4				
		2,798					1.42	1.58	0.5	
129	53.90		6,327	447	14.2	12.9				
		5,386					3.00	1.64	0.9	
130	52.88		5,891	667	8.8	8.4				
		2,746					1.46	1.51	0.5	
131	52.36		7,382	399	18.5	16.2				
		2,218					1.16	1.34	0.5	
132	51.94		7,533	648	11.6	11.1				
		1,636					1.02	1.36	0.3	
133	51.63		7,175	602	11.9	11.0				
		7,022					5.01	1.39	1.4	
134	50.30		7,171	826	8.7	8.4				
		633					0.45	1.34	0.1	
135	50.18		7,725	595	13.0	12.1				
		1,690					1.10	1.31	0.4	
136	49.86		7,534	713	10.6	9.9				
		4,594					2.78	1.29	1.0	
137	48.99		7,924	496	16.0	14.7				
		4,435					2.69	1.36	0.9	
138	48.15		6,827	716	9.5	9.1				
		4,224					2.56	1.31	0.9	
139	47.35		8,452	498	17.0	14.7				
		4,805					2.68	1.2	1.2	
140	46.44		9,446	619	15.3	14.2				
		5,755					3.38	1.11	1.5	
141	45.35		8,649	554	15.6	14.3				
		4,963					2.57	1.16	1.2	
142	44.41		8,543	480	17.8	16.1				
		3,010					1.81	1.17	0.7	
143	43.84		8,613	720	12.0	11.2				
		1,901					1.05	1.08	0.5	
144	43.48		9,951	387	25.7	20.5				
		1,901					0.81	1.02	0.5	
145	43.12		9,620	464	20.7	18.4				
		3,907					2.31	1.06	1.0	
146	42.38		9,273	717	12.9	12.3				
		5,491					3.80	1.00	1.5	
147	41.34		10,786	668	16.1	15.1				
		5,333					3.28	0.97	1.5	
148	40.33		9,779	564	17.3	16.1				
		2,323					1.15	1.00	0.6	
149	39.89		10,253	425	24.1	20.3				
		13,992					7.59	0.94	4.2	
150	37.24		11,128	658	16.9	15.8				
		5,544					3.51	0.90	1.7	
151	36.19		11,053	609	18.1	16.7				
		2,218					1.28	0.91	0.7	
152	35.77		10,985	548	19.9	18.4				
		1,848					0.92	0.84	0.6	
153	35.42		13,001	451	28.8	23.8				
		2,323					1.28	0.81	0.8	
154	34.98		11,811	650	18.2	16.9				
		2,746					1.68	0.83	0.9	
155	34.46		12,355	577	21.4	19.5				
		1,267					0.74	0.81	0.4	
156	34.22		12,201	599	20.4	18.6				8,220
		3,379					1.74	0.80	1.2	
157	33.58		8,495	428	19.8	17.5				
		1,795					0.89	0.96	0.5	
158	33.24		8,654	517	16.7	15.5				
		1,690					0.87	0.92	0.5	
159	32.92		9,291	518	17.9	16.5				
		475					0.25	0.88	0.2	
160	32.83*		9,291	518	17.9	16.5				7,150
		2,059					0.91	0.83	0.7	
161	32.44		7,972	362	22.0	19.3				
		8,131					2.78	0.94	2.4	
162	30.90		7,328	322	22.8	19.0				
		6,758					2.33	0.93	2.0	
163	29.62		8,069	368	21.9	19.3				
		3,854					1.34	0.92	1.2	
164	28.89		7,520	330	22.8	19.4				
		6,125					2.24	0.92	1.9	
165	27.73		8,105	401	20.2	17.6				4,050
		5,544					1.97	0.52	2.9	
166	26.68		7,318	310	23.6	19.6				

* Estimated.

Cross Section No	River Mileage	Length of Reach (Feet)	Cross Sectional Area (Sq Feet)	Width (Feet)	Average Depth (Feet)	Hydr Radius (Feet)	Surface Area (Million Sq Ft)	Average Velocity (FPS)	Travel Time (Hrs)
166	26.68		7,318	310	23.6	19.6			
		686					0.28	0.28	0.7
167	26.55		7,934	490	16.2	14.8			
		475					0.18	0.32	0.4
168	26.46*		5,214	285	18.3	14.7			
		475					0.15	0.40	0.3
169	26.37		5,177	349	14.8	13.3			
		1,954					0.60	0.41	1.3
170	26.00		5,153	269	19.2	15.7			
		3,590					1.15	0.38	2.6
171	25.32		5,755	374	15.4	13.7			
		3,485					1.44	0.36	2.7
172	24.66		6,038	451	13.4	11.5			
		2,059					0.75	0.38	1.5
173	24.27		4,991	276	18.1	14.5			
		5,122					1.81	0.40	3.6
174	23.30		5,621	432	13.0	12.0			
		2,270					0.89	0.37	1.7
175	22.87		5,715	356	16.1	14.3			
		7,550					2.81	0.35	5.9
176	21.44		6,193	388	16.0	14.4			
		2,798					1.00	0.36	2.2
177	20.91		5,457	330	16.5	14.1			
		2,112					0.96	0.38	1.5
178	20.51		5,540	584	9.5	8.9			
		4,646					2.41	0.35	3.7
179	19.63		6,345	455	13.9	12.9			
		5,227					2.59	0.31	4.7
180	18.64		7,176	535	13.4	12.7			
		5,069					2.69	0.31	4.6*
181	17.68		6,491	526	12.3	11.5			
		2,323					1.48	0.27	2.4
182	17.24		9,083	750	12.1	11.2			
		11,246					8.69	0.21	14.9
183	15.11		10,907	795	13.7	13.3			
		1,531					0.98	0.20	2.1
184	14.82		10,092	487	20.7	18.6			
		1,109					0.82	0.14	2.1
185	14.61		18,935	996	19.0	18.0			
		1,639					2.36	0.06	8.0
186	14.30*		54,570	1883	29.0	27.9			
		950					1.79	0.04	6.9
187	14.12		54,550	1883	29.0	27.9			
		3,168					7.61	0.06	10.7
188	13.52		65,613	2924	22.4	22.0			
		7,234					19.42	0.08	26.1
189	12.15		62,840	2445	25.7	24.9			
		5,122					14.25	0.07	20.2
190	11.18		77,643	3118	24.9	24.4			
		8,554					26.49	0.06	39.0
191	9.56		84,722	3075	27.6	27.0			
		3,590					12.61	0.05	19.3
192	8.88		106,450	3947	27.0	26.0			
		1,426					5.42	0.05	8.1
193	8.61		95,812	3657	26.2	25.3			
		2,587					10.14	0.05	14.3
194	8.12		101,096	4185	24.2	23.5			
		1,848					7.34	0.05	10.8
195	7.77		107,380	3761	28.6	27.0			
		1,848					7.20	0.05	10.9
196	7.42		101,870	4027	25.3	25.2			
		2,006					7.70	0.05	11.5
197	7.04		101,717	3644	27.9	26.9			
		2,323					7.58	0.05	12.4
198	6.60		87,740	2885	30.4	29.7			
		4,224					12.11	0.05	20.8*
199	5.80		87,385	2851	30.7	29.9			
		3,643					10.22	0.06	17.5*
200	5.11		83,741	2761	30.3	29.5			
		2,957					8.89	0.06	14.3
201	4.55		88,747	3251	27.3	26.8			
		2,904					8.69	0.06	13.6
202	4.00		77,857	2731	28.5	27.8			
		5,966					17.23	0.06	28.3
203	2.87		91,090	3045	29.9	29.0			
		5,227					15.96	0.05	27.1
204	1.88		93,388	3063	30.5	29.8			
		3,960					12.87	0.05	20.8
205	1.13		93,448	3438	27.2	26.6			
		5,966					20.51	0.05	31.3
	0		93,268	3436	27.1	26.6			

P A R T 2

H Y D R O L O G Y

CHAPTER I. INTRODUCTION

The Sacramento River Basin is located in the central portion of the northern half of the State of California (Plate 1). Although the basin contains over 26,000 square miles, this investigation is concerned primarily with approximately 19,000 square miles of the basin which lie below Shasta Dam and above Collinsville in the Sacramento-San Joaquin Delta. Elevations range from over 14,000 feet at Mount Shasta to sea level at Collinsville. Portions of the basin in the Delta area are even below sea level and are protected from tidal inundation by levees.

The Sacramento River System is fed by 39 surface water drainage basins originating in the Sierra Nevada, Cascade Range, and Coast Range. The drainage boundaries of the Sacramento River and its tributary systems are depicted on Plate 2. Tributary drainage areas are listed in Table 2.1

Table 2.1

DRAINAGE AREAS OF TRIBUTARIES TO SACRAMENTO RIVER

Basin[1] No.	River Mileage	Basin	Drainage Area (mi^2)	Accumulative Drainage Area
1	311	Shasta Lake Inflow[2]		6,690
2	303	Local Keswick Inflow	3.2	6,690
3	302	Spring Creek	14.4	6,710
4	300	Middle Creek	28.7	6,740
5	296	Sulphur Creek	16.2	6,750
6	288	Olney Creek	20.6	6,780
7	288	Clear Creek	244	7,020
8	283	Churn Creek	64.2	7,080
9	280	Stillwater Creek	53.1	7,140
10	279	Cow Creek	540	7,680
11	276	Bear Creek	47.4	7,720
12	275	Ash Creek	36.2	7,760
13	273	Anderson Creek	62.4	7,820
14	272	Cottonwood Creek	928	8,750
15	270	Battle Creek	346	9,100
16	263	Inks Creek	48.7	9,150
17	252	Paynes Creek	103	9,250
18	246	Blue Tent Creek	48.7	9,300
19	245	Dibble Creek	49.9	9,350
20	244	Reeds Creek	64.3	9,410
21	242	Red Bank Creek	115	9,530
22	234	Antelope Creek	246	9,770
23	232	Oat Creek	75.5	9,850
24	229	Elder Creek	175	10,020
25	229	Mill Creek	259	10,280
26	224	Thomes Creek	370	10,650
27	221	Toomes Creek	41.8	10,690
28	219	Deer Creek	236	10,930
29	207	Rice Creek	132	11,060
30	197	Pine Creek	150	11,210
31	194	Big Chico Creek	326	11,540
32	191	Stony Creek	944	12,480
33	139	Butte Creek	691	13,170
34	90	Colusa Basin Drain	1,560	14,730
35	81	Sacramento Slough-Sutter Bypass	386	15,120
36	80	Feather River	5,980	21,100
37	79	Auburn Ravine	377	21,480
38	60	American River	2,160	23,640
39	14	Clear Lake	477	24,110
40	14	Putah-Cache Creeks	2,190	26,300

[1] For geographic location, see Plate 2.
[2] Excluding Goose Lake Basin (1,100 mi^2).

CHAPTER II. MINIMUM FLOWS

To adequately determine the waste assimilative capacity of the Sacramento River in its entirety from Keswick to the mouth, it is necessary to determine the minimum flows which can reasonably be expected. Minimum flows vary by reach of river and by season of the year. Minimum monthly flows in cubic feet per second (cfs) have been estimated for all reaches of the river from Keswick to Steamboat Slough. Data for the 1959-60 water year have been studied in detail as the most recent data available, and therefore, the most indicative of present conditions of development in the Sacramento Valley. It should be pointed out that the 1959-60 water year had below average runoff, amounting to about 75 percent of the 50-year average (1905-06 to 1954-55) on a basin-wide basis.

Minimum flows were estimated at ten representative stations (listed in Table 2.2) on the Sacramento River. These stations were chosen as characteristic of ten reaches of the Sacramento River covering the entire distance from Keswick to Collinsville. Reaches were selected after careful consideration of actual historical stream flow hydrographs of the Sacramento River for the months of June, July, August, and September. These months generally represent critical periods of water supply and water quality impairment in the Sacramento Valley.

Present Conditions

Minimum flows have been derived for various reaches of the Sacramento River based on both present and future conditions of development. Present water supply development in the tributary area is considered to consist of all projects presently operating or under construction. The only exceptions to the above are the Sacramento Municipal Utility

District's Upper American River Development and the Bureau of Reclamation's Corning Canal, which are now under construction but were not assumed to be in operation. The diversion from the Trinity River Division of the Central Valley Project, which is presently under construction, was included in this study under present conditions.

Minimum flows of the Sacramento River under present conditions of development were based upon flows determined at two points on the river; i.e., Keswick and the latitude of the Navigation Control Point (in the vicinity of Wilkins Slough). Flows passing the latitude of the Navigation Control Point will be referred to as flows at the Navigation Control Point for purposes of this report. During periods of flood flows when discharge exceeds the carrying capacity of the Sacramento River, water overflows into constructed flood channels which bypass the Navigation Control Point on the main river channel. Some irrigation return flow may also bypass the Navigation Control Point.

Flows were obtained from a department office report, C.V.O. (Central Valley Operations) No. 2, titled "Effect of Future Development Upon Present Surplus Flows in the Sacramento-San Joaquin Delta", August 1959. These studies were completed in March 1959 and covered the 20-year period 1921-22 to 1940-41. The purpose of these studies was to provide a basic schedule of surplus flows in the Delta, corresponding to a known level of water development and utilization within the tributary drainage area. The present conditions study is based upon modified historical surface water supplies and does not include intensive subsurface storage usage within the watershed. Present demands for water were based on diversions from the Sacramento River during the 1953-54 water year, as published in the Sacramento-San Joaquin Water Supervision Report.

Present mandatory requirements upon the existing works of the Central Valley Project include the following:

1. Navigation requirement of 5,000 cfs with no deficiencies at the critical navigation point which was considered to be the Sacramento River at latitude of Colusa, latitude of mouth of Colusa Drain, or at Chico Landing, dependent on which point had the lowest historical flow. However, the Navigation Control Point was assumed to be in the vicinity of Wilkins Slough gaging station for this study. This assumption was based on the flow distribution for June through September 1960.
2. Delta-Mendota Canal requirement of 1,181,000 acre-feet.
3. Contra Costa Canal requirement of 53,000 acre-feet.
4. City of Vallejo's Cache Slough diversion requirement of 13,000 acre-feet.
5. Riparian and appropriative diversions:
    a. Sacramento River, including bypasses and sloughs amounting to 2,618,000 acre-feet.
    b. Delta uplands diversions from San Joaquin River, Old River, Tom Paine Slough, and Cache Creek, amounting to 309,000 acre-feet.
6. Net consumptive use in the Sacramento-San Joaquin Delta based on land-use patterns determined in 1955.

Future Conditions

Minimum flows of the Sacramento River at Keswick and at the Navigation Control Point for future conditions of development were developed from the "Central Valley Projects (C.V.P.) Operation Study No. 9-5-60",

prepared jointly by the department and the U. S. Bureau of Reclamation. The study is based upon the period 1921-22 to 1953-54.

Future conditions of development include all of those projects and demands as outlined in "Agreement Between the United States of America and the Department of Water Resources of the State of California for the Coordinated Operation of the Federal Central Valley Project and the State Feather River and Delta Diversion Projects", May 16, 1960. Development includes the Trinity River Diversion, Whiskeytown Reservoir Project (Clear Creek), Corning Canal, Tehama-Colusa Canal, Black Butte Reservoir Project (Stony Creek), Oroville Reservoir Project (Feather River), and the Folsom South Canal in addition to all presently operating development. It is believed by the department that most of these developments will be in existence by the year 1990.

Diversions used in the future conditions study were compiled from existing water rights on the Sacramento River. These water rights quantities were employed in the department's Sacramento River Trial Distribution Studies and have been published in a joint report entitled "Report on 1956 Cooperative Study Program -- Water Use and Water Rights Along Sacramento River and in Sacramento-San Joaquin Delta", March 1957, and in supplements on hydrology and water rights by the U. S. Bureau of Reclamation, State Department of Water Resources and the Sacramento River and Delta Water Association.

Irrigation return flows for both present and future conditions were estimated as a percentage of the diversions for each separate river reach. Percentages were assumed to be the same for both present and future conditions. Return flows from diversions were considered to be negligible from November 1 to March 31.

The minimum navigation requirement employed in the future conditions study was 4,000 cfs, with a 1,000 cfs deficiency allowable under certain conditions of project inflow, project and nonproject demands, and combined storage in project reservoirs.

Method

Table 2.3 gives a detailed description of the method employed in derivation of minimum monthly flows for the ten reaches of the Sacramento River. Reach numbers refer to the selected reaches of the Sacramento River and their representative stations as shown in Table 2.2. Minimum flows for reaches (1) through (4) inclusive, are based on low flows at Keswick. Minimum flows for reaches (5) through (8) inclusive, are based on low flows at the Navigation Control Point. Flows for the remaining two reaches are based on the lowest total flow in the river as determined from tributary inflows and flows at the Navigation Control Point. It should be noted that minimum flow studies were not prepared for the Sacramento River from Steamboat Slough to Collinsville since this reach is under strong tidal influence.

Results

Table 2.4 lists the minimum monthly flows under present and future conditions. Daily flows could drop below the specified amounts while operational changes are being made at any of the various projects. Figure 2.1 compares present and future flows for August. These results are presented only as a guide for water quality management planning. They are valid for the particular operating conditions and assumptions outlined above. It is expected that the operations plan will be periodically revised so that better estimates of minimum flows, particularly downstream from the Feather River, will become available.

Table 2.2

REPRESENTATIVE SACRAMENTO RIVER
STATIONS AND REACHES

Reach No.	River Mile	Reach of Sacramento River	Represented by Station
1	300-297	Keswick to Anderson-Cottonwood I.D. Diversion	Below Keswick
2	297-270	Anderson-Cottonwood I.D. Diversion to Battle Creek	Above Clear Creek
3	270-242	Battle Creek to Corning and Tehama-Colusa Canal Diversions	At Iron Canyon G.S.
4	242-205	Corning and Tehama-Colusa Canal Diversions to Glenn-Colusa I.D. Diversion	Below Corning and Tehama-Colusa Canal Diversions
5	205-164	Glenn-Colusa I.D. Diversion to R. D. 1004 Diversion	Above R.D. 1004 Diversion
6	164-119	R.D. 1004 Diversion to Sutter Mutual Water Company Diversion	Above Sutter Mutual Water Company Diversion
7	119- 90	Sutter Mutual Water Company Diversion to Colusa Basin Drain	Navigation Control Point
8	90- 80	Colusa Basin Drain to Feather River	Above Feather River
9	80- 60	Feather River to American River	Above American River
10	60- 33	American River to Steamboat Slough	Above Steamboat Slough

TABLE 2.3

BASIS OF COMPUTATION
FLOW AT REPRESENTATIVE SACRAMENTO RIVER STATIONS

Reach No.		Method of Computation
1	Equals flow of Sacramento River at Keswick	
		(Based on low flows at Keswick.)
2	Equals	1
	Minus	Diversions between Keswick and Clear Creek
	Plus	Return flows between Keswick and Clear Creek
		(Based on low flows at Keswick.)
3	Equals	1
	Minus	Historical flow of Sacramento River at Shasta Dam
	Plus	Historical flow of Sacramento River near Red Bluff
	Minus	Historical flow of Clear Creek
	Plus	Whiskeytown Reservoir releases to Clear Creek
	Minus	Increase in diversions between Keswick and Red Bluff (future conditions only)
		(Based on low flows at Keswick.)
4	Equals	3
	Plus	Flow of Redbank Creek group
	Minus	Diversions to Corning and Tehama-Colusa Canals (future conditions only)
		(Based on low flows at Keswick.)
5	Equals	6
	Plus	Diversions between Sutter Mutual Water Company diversion and to above R. D. 1004 diversion
	Minus	Butte Creek near Chico
	Minus	Return flows between S.M.W.C. Diversion and R. D. 1004 diversion
		(Based on low flows at Navigation Control Point.)
6	Equals	7
	Plus	Diversions between R. D. 108 gaging station and to above Sutter Mutual Water Company diversion
	Minus	Return flows between R. D. 108 gaging station and S.M.W.C. Diversion
		(Based on low flows at Navigation Control Point.)
7	Equals flow at Navigation Control Point	
		(Based on low flows at Navigation Control Point.)

Table 2.3

BASIS OF COMPUTATION
FLOW AT REPRESENTATIVE SACRAMENTO RIVER STATIONS
(continued)

Reach No.		Method of Computation
8	Equals	7
	Plus	Return flows between R. D. 108 gaging station and Feather River
	Minus	Diversions between R. D. 108 gaging station and Feathe River
		(Based on low flows at Navigation Control Point)
9	Equals	7
	Plus	Return flows between R. D. 108 gaging station and American River
	Plus	Feather River at Oroville (Oroville Reservoir releases to Feather River - Future Conditions only)
	Plus	Yuba River near Smartville
	Plus	Bear River near Wheatland
	Minus	Diversions between R. D. 108 gaging station and American River
		(Based on lowest total flow.)
10	Equals	9
	Plus	Folsom Reservoir releases to American River
	Minus	Diversions between American and Sacramento
		(Based on lowest total flow.)

Table 2.4

HYDROLOGY
MINIMUM FLOWS - SACRAMENTO RIVER
Cubic Feet Per Second
(Based on Monthly Flows for the Period 1921-22 to 1940-41)

PRESENT CONDITIONS OF DEVELOPMENT

Reach No.	River Mile	Reach Description	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	300-297	Keswick to Anderson-Cottonwood I. D. Diversion	4,600	3,900	2,600	2,600	2,600	2,300	2,400	4,400	6,400	7,900	8,400	5,900
2	297-270	Anderson-Cottonwood I. D. Diversion to Battle Creek	4,300	3,800	2,600	2,600	2,600	2,300	2,100	4,000	6,000	7,500	8,100	5,600
3	270-242	Battle Creek to Corning and Tehama-Colusa Canal Diversion	5,400	5,400	4,500	5,300	4,300	3,300	4,900	7,100	7,600	8,600	8,800	6,300
4	242-205	Corning and Tehama-Colusa Canal Diversions Glenn-Colusa I. D. Diversion	5,400	5,400	4,500	5,300	4,300	3,300	5,000	7,500	7,700	8,600	8,800	6,300
5	205-164	Glenn-Colusa I. D. Diversion to R. D. 1004 Diversion	5,000	4,900	4,900	4,800	4,900	4,700	5,300	6,800	6,900	7,100	6,900	5,800
6	164-119	R. D. 1004 Diversion to Sutter Mutual Water Company Diversion	5,100	5,000	5,000	5,000	5,000	5,000	5,400	6,600	6,500	6,500	6,400	5,700
7	119- 90	Sutter Mutual Water Company Diversion to Colusa Basin Drain	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
8	90- 80	Colusa Basin Drain to Feather River	5,700	5,000	5,000	5,000	5,000	5,000	5,000	5,800	5,500	5,200	5,600	6,400
9	80- 60	Feather River to American River	7,400	6,500	6,500	7,000	8,000	8,200	9,400	7,900	6,900	6,300	6,900	7,900
10	60- 33	American River to Steamboat Slough	7,900	7,000	7,500	7,400	8,900	8,600	9,700	8,600	9,400	9,500	10,300	9,300

FUTURE CONDITIONS OF DEVELOPMENT

Reach No.	River Mile	Reach Description	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
1	300-297	Keswick to Anderson-Cottonwood I. D. Diversion	4,000	3,900	2,600	2,600	2,600	2,300	2,300	4,500	6,900	7,300	9,100	5,300
2	297-270	Anderson-Cottonwood I. D. Diversion to Battle Creek	3,700	3,900	2,600	2,600	2,600	2,300	2,100	4,200	6,500	6,900	8,800	5,000
3	270-242	Battle Creek to Corning and Tehama-Colusa Canal Diversions	4,200	4,400	3,200	3,800	4,300	3,300	4,200	5,200	7,700	7,300	9,100	5,400
4	242-205	Corning and Tehama-Colusa Canal Diversions Glenn-Colusa I. D. Diversion	3,700	4,400	3,200	3,800	4,300	3,200	3,900	4,300	6,500	5,900	7,900	4,700
5	205-164	Glenn-Colusa I. D. Diversion to R. D. 1004 Diversion	3,000	4,100	3,600	4,500	4,900	3,800	3,800	4,900	4,900	5,400	5,200	3,800
6	164-119	R. D. 1004 Diversion to Sutter Mutual Water Company Diversion	3,100	4,200	3,700	4,600	5,100	4,000	3,700	4,400	4,500	4,500	4,400	3,600
7	119- 90	Sutter Mutual Water Company Diversion to Colusa Basin Drain	3,000	4,200	3,700	4,600	5,100	4,000	3,000	3,000	3,100	3,000	3,000	3,000
8	90- 80	Colusa Basin Drain to Feather River	3,700	4,200	3,700	4,600	5,100	4,000	3,100	3,500	3,500	3,200	3,600	4,000
9	80- 60	Feather River to American River	6,700	5,500	5,100	5,800	6,500	7,100	4,500	4,500	6,000	7,900	10,000	10,000
10	60- 33	American River to Steamboat Slough	6,900	5,900	5,400	6,000	6,600	7,200	4,600	4,600	6,500	7,900	10,000	10,100

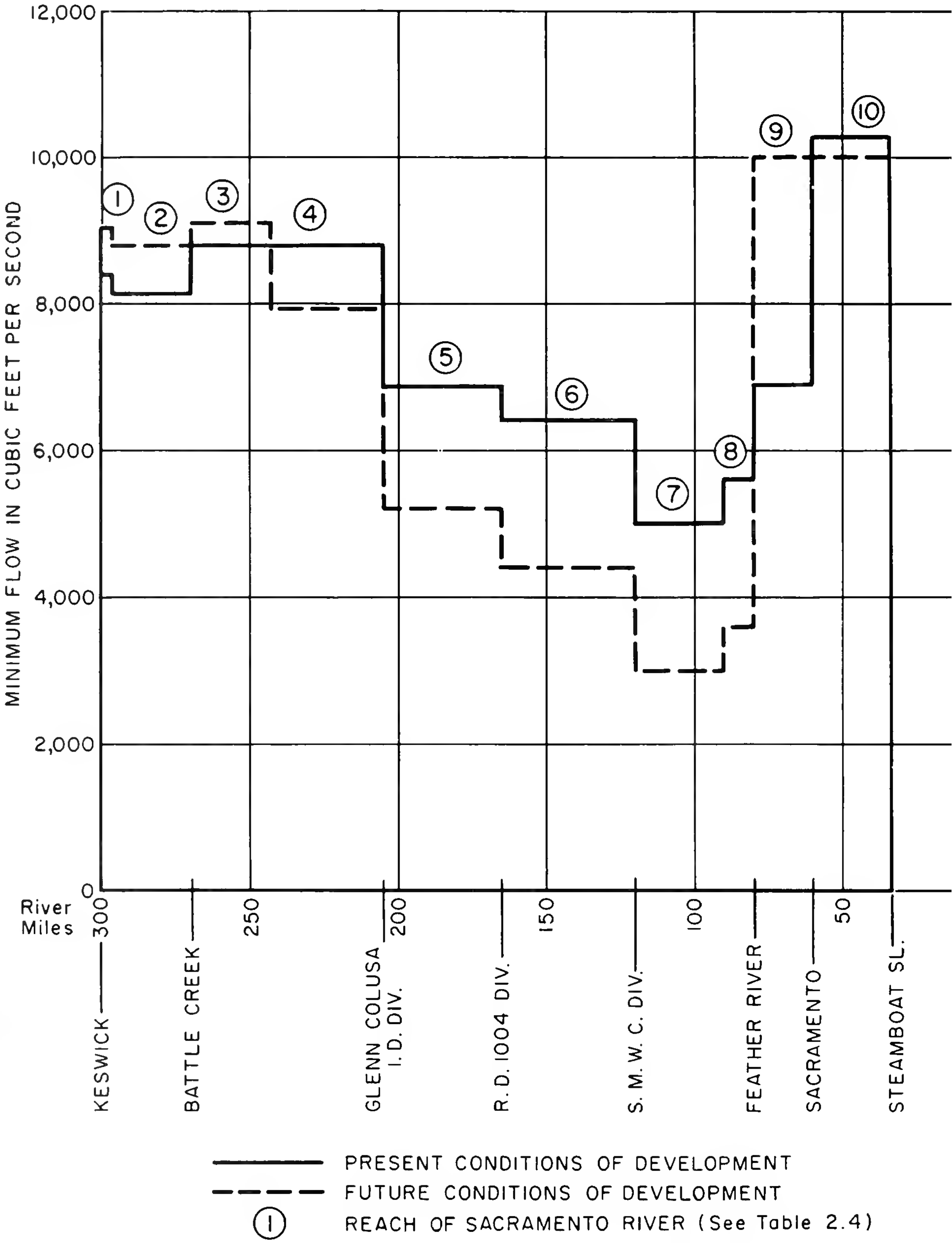


Figure 2.1. AVERAGE MINIMUM MEAN DAILY FLOWS FOR AUGUS

PART 3

WATER UTILIZATION

CHAPTER I. INTRODUCTION

The dramatic feature of water supply and utilization in California is its geographic distribution. The major sources of water are located in the northern part of the State where the waters are generally wasted into the ocean. Central and southern regions, rich in productive land areas, lack sufficient water supplies. Over 70 percent of the stream flow in California occurs north of a line drawn through Sacramento. The streams of the Sacramento River Basin furnish about 32 percent of the total for the State. On the other hand, 77 percent of the present consumptive water requirement and 80 percent of the future ultimate requirement is south of the same line.

Beneficial water uses in the Sacramento Valley presently are municipal and industrial water supply, irrigation, power generation, recreation, fish and wildlife, navigation, and salinity control in the Sacramento-San Joaquin Delta. The discharge of wastes is intimately related to many of these beneficial uses.

Related Investigations and Reports

The following reports have been drawn upon in discussing water utilization:

California State Department of Fish and Game. "Effects of Delta Water Facilities on Fish and Wildlife in the Sacramento-San Joaquin Delta." Office report. February 1961.

California State Water Resources Board. "Water Utilization and Requirements of California." Bulletin No. 2. June 1955.

California State Department of Water Resources, Division of Design and Construction. "Flood Flows and Stages in Sacramento and Northern San Joaquin Valleys, 1954-56." Bulletin No. 16. February 1957.

California State Department of Water Resources, Division of Resources Planning. "The California Water Plan." Bulletin No. 3. May 1957.

California State Department of Water Resources. "Dams Within Jurisdiction of the State of California." Bulletin No. 17. January 1958.

----. "Water for California." Second Annual Progress Report, 1957-58.

California State Department of Water Resources, Division of Resources Planning. "Irrigation and Water Storage Districts in California for 1956-58." Bulletin No. 21. March 1960.

----. "Northeastern Counties Investigation." Bulletin No. 58. June 1960.

California State Department of Water Resources. "Delta Water Facilities." Bulletin No. 76. December 1960.

California State Department of Water Resources, Division of Resources Planning. "Surface Water Flow for 1959." Bulletin No. 23-59. May 1961.

----. "Surface Water Flow for 1960." Bulletin No. 23-60. September 1961.

Parson, Brinkerhoff, Hall and MacDonald, Engineers. "Sacramento-San Joaquin Delta Master Plan for Recreation." Report to California State Department of Water Resources. December 1958.

CHAPTER II. LAND USE

The Sacramento River Basin includes the northern 45 percent of the Central Valley area and occupies 26,960 square miles between the Delta and the northeastern corner of the State. Sixty-four percent of the watershed area is classified as mountain or foothill lands. Twenty-two percent of the basin area is above 5,000 feet elevation. The valley floor covers an area of nearly 4,950 square miles, averages about 30 miles in width and 150 miles in length, and ranges in elevation from below sea level in the Delta area to 300 feet near the foothills (Plate 1).

Present Land Use

Table 3.1 presents estimated present land use and water requirements.

The 1960 population in northern Central Valley counties was 1,142,420. About two-thirds of the population is located along the Sacramento River flood plain. The 143,000 acres of urban development represent an area increase since 1955 of 18 percent.

Table 3.1 lists 1,900,300 acres being used as irrigated lands during 1960. Seventy percent (1,320,500 acres) were in counties bordering the Sacramento River.

Probable Future (1990) Land Use

Projected urban land requirements in 1990 are shown in Table 3.1. The estimated 1990 population is 3,092,400, an increase of 171 percent. Of the total increase, almost 45 percent is expected in Sacramento County. Urban areas are predicted to grow from 143,000 to 336,400 acres, an increase of 136 percent during the next 30 years.

Land areas used for irrigated agriculture are estimated to expand from 1,900,300 to 2,747,400 acres by 1990, amounting to an increase of 45 percent.

Table 3.1

ESTIMATED POPULATION AND IRRIGATION-URBAN DEMANDS
FOR WATER IN THE SACRAMENTO RIVER BASIN

County	Irrigation Requirements*				Urban Requirements*			
	1960		1990		1960		1990	
	Area	Water	Area	Water	Area	Water	Area	Water
Butte	181.0	760.2	270.0	1,080.0	12.7	18.4	28.7	57.4
Colusa	180.0	855.6	254.0	1,130.3	2.9	4.2	5.9	12.0
El Dorado	8.0	31.9	22.0	83.6	3.6	5.2	11.5	23.1
Glenn	152.5	744.2	245.0	1,068.2	3.0	4.3	8.6	17.4
Lassen	75.5	225.0	94.0	274.5	2.5	3.7	7.3	14.7
Modoc	152.0	308.6	181.6	350.5	2.2	3.2	4.6	9.3
Nevada	7.9	28.4	20.1	68.3	3.2	4.6	10.4	20.8
Placer	45.0	201.6	81.0	320.0	8.8	12.7	22.1	44.4
Plumas	54.0	113.4	66.0	138.6	2.9	4.2	5.9	12.0
Sacramento	153.0	596.7	218.0	795.7	58.7	85.1	127.0	254.2
Shasta	67.0	261.3	100.1	335.3	8.6	12.5	19.5	39.0
Sierra	23.9	50.2	27.5	57.8	0.6	0.9	1.7	3.4
Siskiyou	143.5	430.5	184.0	552.0	5.5	8.0	12.3	24.8
Solano	87.0	348.0	157.5	598.5	4.0	23.2	11.8	94.4
Sutter	230.0	917.7	284.5	1,081.1	5.3	7.6	11.9	23.8
Tehama	66.0	242.2	127.7	434.2	3.9	5.6	11.2	22.5
Yolo	204.0	836.4	287.0	1,090.6	9.9	14.4	22.4	44.8
Yuba	70.0	291.2	127.4	484.1	4.7	6.8	13.6	27.3
TOTAL	1,900.3	7,243.1	2,747.4	9,943.3	143.0	224.6	336.4	745.3

* Area in 1,000 acres; water required in 1,000 acre-feet per year.

CHAPTER III. DOMESTIC WATER SUPPLY

Background

The past years have seen the development of many community water systems along the Sacramento River. Some of the systems have used the river water as a source of supply either for limited periods or for their entire life-span. Others have always used ground water sources.

The northernmost domestic water intake on the river supplies water to the City of Redding. The Redding Water Company established the system in 1896 and pumped river water directly from an intake southeast of town to the consumers. Because of increased concern over the bacteriological quality of the river water below town, the intake was moved four miles upstream in 1908, and in 1916 chlorination was started. In the early years, the water system passed through many hands, until in 1941 the City of Redding became the owner. Additional treatment facilities have been gradually added to the system since 1916.

Water is supplied by the Rockaway Water Company to 24 residences in a subdivision east of Redding. The system was constructed in 1940 with a well on the bank of the Sacramento River as the sole source of supply. In 1955, the well was abandoned and an intake pipe was extended out into the main current of the Sacramento River. A hypochlorinator was installed in 1956.

The Enterprise Public Utility District, serving another residential area east of Redding, constructed an infiltration gallery near the east bank of the river in 1951 and provided chlorination in 1954.

Red Bluff, approximately 50 river miles below Redding, has not used Sacramento River water for its domestic supply. The town obtains its water from a tributary of the Sacramento River and a well system.

In 1955 the State Department of Public Health was asked by the city for an opinion as to the possibility of using the Sacramento River as a source of domestic water. In reply, it was pointed out that the sewage discharge from Redding entered the river upstream from Red Bluff and the water at Red Bluff, "should receive a reliable degree of treatment including at least coagulation, settling, rapid sand filtration, disinfection, and probably pH adjustment." No further action has been taken by the city to use the river water.

At Colusa, a private water company served the town with a mixture of well water and river water until 1910. In that year a municipal system was constructed, using wells as the source of supply. A river pumping plant was used to supplement the well supply for fire protection. Inasmuch as untreated Sacramento River would be pumped into the domestic water system in the event of a fire, a serious health hazard existed. Additional ground water supplies were developed and the river pumping station was abandoned in 1916.

Knights Landing has always had individual well supplies for domestic purpose and has used river water for fire protection. The fire hoses are connected directly to a portable pump and there are no cross-connections with the domestic supplies.

The City of Sacramento has been the major user of Sacramento River water for domestic purposes since 1850. In the early days, river water was diverted directly into the distribution system. A few years after the initial construction of the system, a destructive fire proved that the water supply facilities were not adequate, and in 1854, a new city-owned water system was placed in service. The rise in the typhoid rate at Sacramento showed the need for treatment of the diverted water, and in 1915, the city provided chlorination at the intake. The excessive

degree of bacterial contamination, particularly during low flor periods in the river, necessitated additional treatment and a rapid sand filtration plant was completed in 1924. The filtration plant was expanded through the years and in 1940, wells were developed to supplement the surface water supply.

Broderick, a community across the river from Sacramento, was supplied with untreated Sacramento River water in the early 1900's. Eventually, a chlorinator was installed at the intake but was often out of operation. In 1929 the water company developed a ground water source of supply and abandoned its river intake.

The City of Vallejo had for many years considered the possibility of installing an intake on an arm of Cache Slough, a waterway branching from the Sacramento River. In 1926 the project was proposed but was later dropped. The city, together with large nearby military installations, underwent a rapid population growth during and after World War II. A new major source of water was needed and in 1950 the city constructed a complete treatment plant and transmission main to serve Vallejo and the greater Vallejo area with Sacramento River water diverted at Cache Slough.

Rio Vista, at the lower end of the river, had an intake for its domestic water supply in the early 1900's on the Sacramento River. In 1911 it was pointed out that 14 cases of typhoid in the city were probably due to the use of this source of supply. Consequently the city installed pressure sand filters at its river pumping station. No preliminary treatment was provided. Constant clogging of the filter material resulted in high maintenance costs which led to the plant being abandoned in 1914 when the city sank wells in the bank of the river for its water supply.

In addition to major diversions for domestic supply, there have been a number of individual labor camps located below Sacramento which, until 1930, had diverted river water for drinking purposes. The practice was discontinued when typhoid cases in the camps proved the water was unfit for human consumption without adequate treatment. In addition, many river boats which plied the river from Colusa to the Bay area, and house boats which were berthed at and below Sacramento, often obtained domestic water directly from the river.

The periods of time during which domestic water systems have diverted Sacramento River water are summarized in Table 3.2

Table 3.2

USE OF SACRAMENTO RIVER WATER
BY DOMESTIC WATER SYSTEMS

Water System	Period of Use
Redding	1896 - present
Rockaway	1955 - present
Enterprise	1951 - present
Colusa	1900 (est) - 1910
Broderick	1900 (est) - 1929
Sacramento	1850 - present
Vallejo	1950 - present
Rio Vista	1890 (est) - 1916

Present Domestic Water Systems

Five separate domestic water systems presently derive all or most of their water from the Sacramento River. The systems serving Sacramento, Redding, Enterprise, and Rockaway Subdivision have intakes

on the main stem of the river. That which serves the greater Vallejo area of Solano County takes water from Cache Slough, a waterway branching from the main stem of the river. The total population that drinks Sacramento River water is about 273,000. Detailed information of these systems is presented below. An estimated additional 100,000 persons are served with water from the Sacramento-San Joaquin Delta by the Contra Costa County Water District of the California Water Service Company and the City of Antioch. This water receives complete treatment.

City of Redding Municipal Water System

The City of Redding derives all its domestic water from the Sacramento River through an intake near the western bank above the town. The water is pumped to a treatment plant on the hills north of town where chlorination and settling is provided. Alum and lime feeders and flocculation equipment have been recently installed and may be used to aid turbidity removal during the winter periods of high turbidity.

Redding System	1960
Estimated population served	12,500
Average total daily pumpage (gallons)	3,739,000
Maximum total daily pumpage (gallons)	9,270,000
Average gallons per capita per day	299

Rockaway Water Company

The water company has an intake pipe extending out into the Sacramento River from a pumping station located on the bank. Water is pumped to a pressure tank and chlorinated.

Rockaway System	1960
Estimated population served	84
Average daily total pumpage (gallons)	7,500
Maximum daily pumpage (gallons)	15,000
Average gallons per capita per day	90

Enterprise Public Utility District Water System

Enterprise is a residential community located across the Sacramento River from Redding. During its early growth the residences were served by private wells. In 1951 the Public Utility District installed an infiltration gallery on a gravel bar at the east side of the Sacramento River at river mile 294, immediately north of the Highway 44 Bridge. During flood flows the gallery has been inundated; however, it is normally 50 feet from the river flow. In 1951, chlorination facilities were installed at the pumping plant at the gallery and in 1958 and 1959, two wells were added to the system to supplement the surface water supply.

Enterprise System	1960
Estimated population served	4,700
Total yearly production (gallons)	54,000,000
Average daily summer production (gallons)	250,000
Average daily winter production (gallons)	37,500

The City of Sacramento Municipal Water System

The City of Sacramento presently derives 80 to 85 percent of its domestic water from the Sacramento River. River water enters an intake structure 1,000 feet downstream from the confluence of the American and Sacramento Rivers and is pumped to a 64 MGD rapid-sand filtration plant. Water entering the treatment plant is a mixture of American and Sacramento River waters. Treatment consists of prechlorination, grit removal,

flocculation and sedimentation followed by filtration and postchlorination. After treatment, the water is pumped to a single large service area that includes virtually the entire area within the city limits. The surface water supply is supplemented by ground water from approximately 55 deep wells that supply water to other service areas in the southern end of the city. Because of higher iron, manganese and hardness content of ground water in the area, surface water is the preferred source of supply.

In 1955, a Ranney Water Collector was constructed beside the river levee at the western edge of the city. The collector proved capable of providing 14 MGD; however, the water had high iron and manganese concentrations which made it unsuitable for domestic use without treatment.

Sacramento System	1959	1960
Estimated population served	139,600	139,400
Total water pumped (gallons)	14,434,000,000	13,785,000,000
Average total daily pumpage (gallons)	39,500,000	37,660,000
Maximum total daily pumpage (gallons)	69,900,000	71,000,000
Minimum total daily pumpage (gallons)	20,800,000	14,400,000
Average gallons per capita per day*	283	259

* Reduction in per capita consumption obtained by public relations program.

City of Vallejo Water System

The City of Vallejo Water System serves approximately 120,000 persons throughout the central and western portion of Solano County. Approximately 74 percent of the water delivered to this population is derived from Cache Slough, a waterway branching from the Sacramento River. This source of supply was developed in 1954 because of the increasing water needs of the City of Vallejo and adjacent areas.

The raw water is chlorinated at the Cache Slough pumping station for slime control. The water is then treated for domestic use. One

treatment plant with a 3 MGD capacity serves Travis Air Force Base. The major portion of the Cache Slough water is stored at Cordelia Reservoir, which has a capacity of 15,000,000 gallons, prior to treatment at the 14 MGD Fleming Hill Treatment Plant. Cache Slough water is also transmitted to the City of Fairfield water treatment plant. The treatment plants provide prechlorination, flocculation and sedimentation followed by rapid sand filtration, fluoridation, pH adjustment and postchlorination.

Vallejo System	1960-61
Estimated population served	115,000
Total water pumped (gallons)	4,343,938,000
Average total daily pumpage (gallons)	11,900,000
Maximum monthly average (gallons/day)	17,284,000
Minimum monthly average (gallons/day)	7,427,000

Future Domestic Water Requirements

The extent to which the estimated 1990 urban water requirements, presented in Table 3.1, will be met by Sacramento River water depend upon both the firm supply and the quality from alternate sources. In the Redding area, users of Sacramento River water contend with high turbidities and "aggressive" water. In order to obtain a source of supply that is less subject to seasonal change, Trinity River water may be used. Water is to be diverted at Trinity Dam through a tunnel discharging into Spring Creek and thence into the Sacramento River about ten miles above Redding. This water could constitute a major supply for the Redding area.

Although the City of Red Bluff does not use Sacramento River water at the present time, the cost of producing ground water to meet future needs of the city may cause the city to revert to the Sacramento River as a source of supply. The feasibility of providing the required

water treatment would depend upon the cost of developing additional ground water supplies.

At the City of Sacramento, the water needs of the city have rapidly approached the present capacity of the treatment works. Extensive plans have been made by the city to meet future needs. These plans include expansion of the existing treatment facilities on the Sacramento River from a present capacity of 64 MGD to a capacity of 122 MGD by 1975. In addition, a 60 MGD treatment plant which will divert water from the American River approximately 7.5 miles above the mouth is scheduled for completion by 1963. The ultimate capacity of the American River plant will be 330 million gallons per day.

The city's Ranney Collector which is at the south end of the city and which extends out under the Sacramento River has not been used because of high concentrations of iron and manganese. These constituents are not present in such quantities in the river water and their presence indicates that the water gathered in the collector is predominantly ground water. Treatment facilities for removal of the iron and manganese are scheduled for completion late in 1962 and this supply will serve a portion of the southern end of the city. The existing wells may be put on a standby basis for emergency use only.

In the future the major use of Sacramento River water for domestic water purposes will result from implementation of The California Water Plan. Numerous communities will use Sacramento River water which has been diverted through aqueducts to the coastal, central, and southern portions of the State. Contractual agreements with the various water agencies which will receive water from the State water facilities provide for a high degree of purity which can be maintained only by a water quality management program which considers all beneficial uses, sources of degradation and concomitant requirements for disposal of wastes.

CHAPTER IV. IRRIGATION WATER SUPPLY

Irrigated agriculture presently constitutes the greatest demand upon the total developed water supply in the Sacramento Valley. The growth of irrigated agriculture, however, has been slow since the area normally is suitable for the production of dry-farmed crops. A drought in 1863 and 1864 resulted in some consideration of irrigation, but it was not until after 1900 that irrigation became significant. The California Water Plan was conceived in the 1920's. Part of this plan was realized by the construction of Shasta Dam, which is a part of the Central Valley Project. The primary objective of the project is to supply irrigation water to deficient areas in the Sacramento and San Joaquin Valleys.

During the period 1950-59, the average annual diversion from the Sacramento River between Redding and Sacramento was 1,922,000 acre-feet which was applied to a total of 290,400 acres in the basin. A much smaller amount was diverted below Sacramento for use in the Delta.

Present Supply

Present monthly irrigation water demands within a 12-month period generally vary from zero during winter rainy months to more than 15 percent of the seasonal total during a dry summer month.

Irrigation water requirements (Table 3.1) have been estimated by determining the irrigation efficiency of service areas of the Sacramento River Basin. Irrigation efficiency is determined from the ratio of consumptive use of applied irrigation water to the gross amount of irrigation water delivered to the service areas. In developing water requirements, consideration was given to soil conditions, position in relation to sources of water supply, consumptive use of water, and irrigation efficiency.

Table 3.3 lists major facilities that divert Sacramento River water for irrigation. The greatest diversions are made from June through August.

Table 3.3

MAJOR DIVERSIONS FROM THE SACRAMENTO RIVER, 1960

River Mile	Water User	Total Diversion, acre-feet	Maximum Monthly Diversion, cfs
297.7R	Anderson-Cottonwood Irrigation District	174,700	395
205.1R	Glenn-Colusa Irrigation District	768,100	2,320
205.0R	Jacinto Irrigation District	85,600	175
174.1R	Princeton-Codora-Glenn Irrigation District	65,600	150
118.9L	Sutter Mutual Water Company	213,100	760
118.3R	Reclamation District No. 108	95,100	350
99.0R	Reclamation District No. 2047	64,400	220
71.2R	Woodland Farms, Incorporated	65,200	260
27.3L	Delta-Mendota Canal	1,389,200	3,925

Probable Future Demands

Estimated irrigation water demands for the period 1960 and 1990 are presented in Table 3.1. By 1990, estimated irrigation requirements of the Sacramento Basin will exceed the 1960 requirements by 36 percent. Requirements of Butte, Colusa, Glenn, Solano, and Yolo Counties will constitute over one-half of the estimated increase.

In addition, water flowing in the Sacramento River will ultimately be utilized, under The California Water Plan, by the diversion of flow through the California Aqueduct to users in the San Joaquin Valley

and other sections of southern California. The Delta Division of the California Aqueduct System will provide for transfer of water across the Sacramento-San Joaquin Delta from northern areas of water surplus to central and southern areas of deficiency. After allowing for ultimate requirements in upstream areas and on the Sacramento Valley floor, about 8,700,000 acre feet per year will be available to serve present and future local and export requirements at the Delta.

Rice Field Study

Ideal weather, soil conditions, topography and an abundant water supply combine to make the Sacramento Valley one of the major rice growing areas in the United States. About 45 percent of land irrigated by Sacramento River is devoted to the rice which requires between six and seven acre-feet per year per acre. Since most of the water drained from rice fields eventually discharges into the river, a special study was made of a specific rice field to determine changes in quality from the point of supply to the drain. Although the data are specific to the one field, they are considered reasonably representative of the degradation that occurs in most rice fields. The actual effects of irrigation drainage on the quality of the Sacramento River are discussed in Appendix B.

Rice Farming and Irrigation Practice

Rice fields are prepared for seeding in late April and early May. The land is plowed and harrowed, new levees are constructed and irrigation boxes are installed. Common practices provide, immediately before seeding, flooding of the land to a depth of 6 to 9 inches. The rice seed is then broadcast onto the flooded areas by low-flying planes. A continuous supply of water is needed to compensate for evaporation, percolation and to maintain movement of water through the field. The

water may take from several days to several weeks to pass from inlet to outlet. An initial high water level is necessary to control weed growths. After the first few weeks of operation the water level can be lowered a few inches.

After the growing period, the flooded fields are quickly drained and allowed to dry for several weeks so that harvesting equipment can be moved onto the field. In order to expedite drainage of the field, holes are opened in the levees by dynamiting.

Rice Field Acreage

A total of 128,100 acres of rice fields from Sacramento to Red Bluff were irrigated with Sacramento River water during 1959. There is no rice acreage above Red Bluff. Table 3.4 shows the distribution of rice acreage for 1959 by river reach:

Table 3.4

RICE FIELD ACREAGES, 1959

Reach	Length of Reach in River Miles	Area of Rice Fields in Acres
Sacramento-Verona	20	8,820
Verona-Knights Landing	14	7,790
Knights Landing-Wilkins Slough	29	12,240
Wilkins Slough-Colusa	26	30,810
Colusa-Butte City	26	12,740
Butte City-Red Bluff	83	55,700
TOTAL	198	128,100

Possible Sources of Degradation

Water used for irrigation may be degraded by animals and birds, fertilizers, weedicides and insecticides, concentrations of salts by evaporation and transpiration, and minerals leached from the soil.

Animals and Birds. Sheep are commonly used to control grass and weed growth on the narrow levees within the rice fields. Usually about five sheep are used per mile of levee. The sheep remain on the levee so that droppings, for the most part, also remain on the levee. Wildlife in the fields include waterfowl, blackbirds, and pheasants. Waterfowl are attracted to the fields during the irrigation periods.

Fertilizers. Most rice fields in the Sacramento Valley require supplemental nitrogen and, to a lesser extent, phosphorous. The nitrogen content in the soil is improved by rotation of rice with a cover crop such as vetch, every one, two, or three years. Chemical fertilizers may be needed to supplement the nitrogen supply or used as the sole source. Nitrogen and phosphate fertilizers are usually added to the soil within one week before water is turned onto the fields. Supplementary nitrogen fertilization may be made within 40 to 60 days after planting if the early application was inadequate.

Weedicides. Two popular types of weedicides used on rice fields are 2,4-D and MCPA. These chemicals are sprayed on the field from airplanes, usually 55 to 65 days after planting, at rates normally ranging from 12 to 16 ounces per acre.

Insecticides. Insecticides are used only on a small percentage of the rice fields in Sacramento Valley. Use of insecticides is related to air temperature; several days below 50°F during the growing season may necessitate their use to control the leaf miner. Two of the most common insecticides are Dieldrin applied at a rate of about four ounces per acre and technical DDT applied at rates of 1-1/2 to 2 pounds per acre. These insecticides are generally sprayed from airplanes.

Great numbers of mosquitoes may be found in rice fields, especially when growing plants are in the water. DDT is one of the most common chemicals used for controlling mosquitoes.

Concentration of Salts Due to Evaporation and Transpiration. Drainage from the rice field will be more mineralized than the applied water due to loss of water from evaporation and transpiration with resulting increases in salt concentrations in the remaining water.

Minerals Leached from the Soil. Water moving through the soil will become increasingly mineralized by dissolving salts from the soil.

Sopwith Rice Field

The James R. Sopwith rice field occupies 55 acres about ten miles north of Sacramento as shown on Figure 3.1. The soil is Alamo adobe clay, a very fine textured, dark gray clay with adobe structure. At depths of 28 to 36 inches, an iron and silica cemented hardpan occurs.

Cultivation of the field was completed April 13, 1960. On April 15, dry fertilizer, Shell Ammonium Sulfate (21-0-0), with 21 percent ammonia nitrogen and 24 percent combined sulfur was applied at a rate of 150 to 200 pounds per acre. Water was turned onto the field April 19, and kept high for 21 days to kill the weeds, after which the water level was lowered to allow the rice to grow. "Colusa" rice was sown onto the field by airplane on April 21. As the rice grew, the water depth was increased to about six or eight inches. Prior to planting, the rice was soaked in water. During the first week of June, about 15 sheep were let onto the levees to keep the grass short. On June 22, the weedicide, "MPCA", applied at a rate of 12 ounces per acre, was sprayed onto the field by airplane. Water supply to the field was discontinued

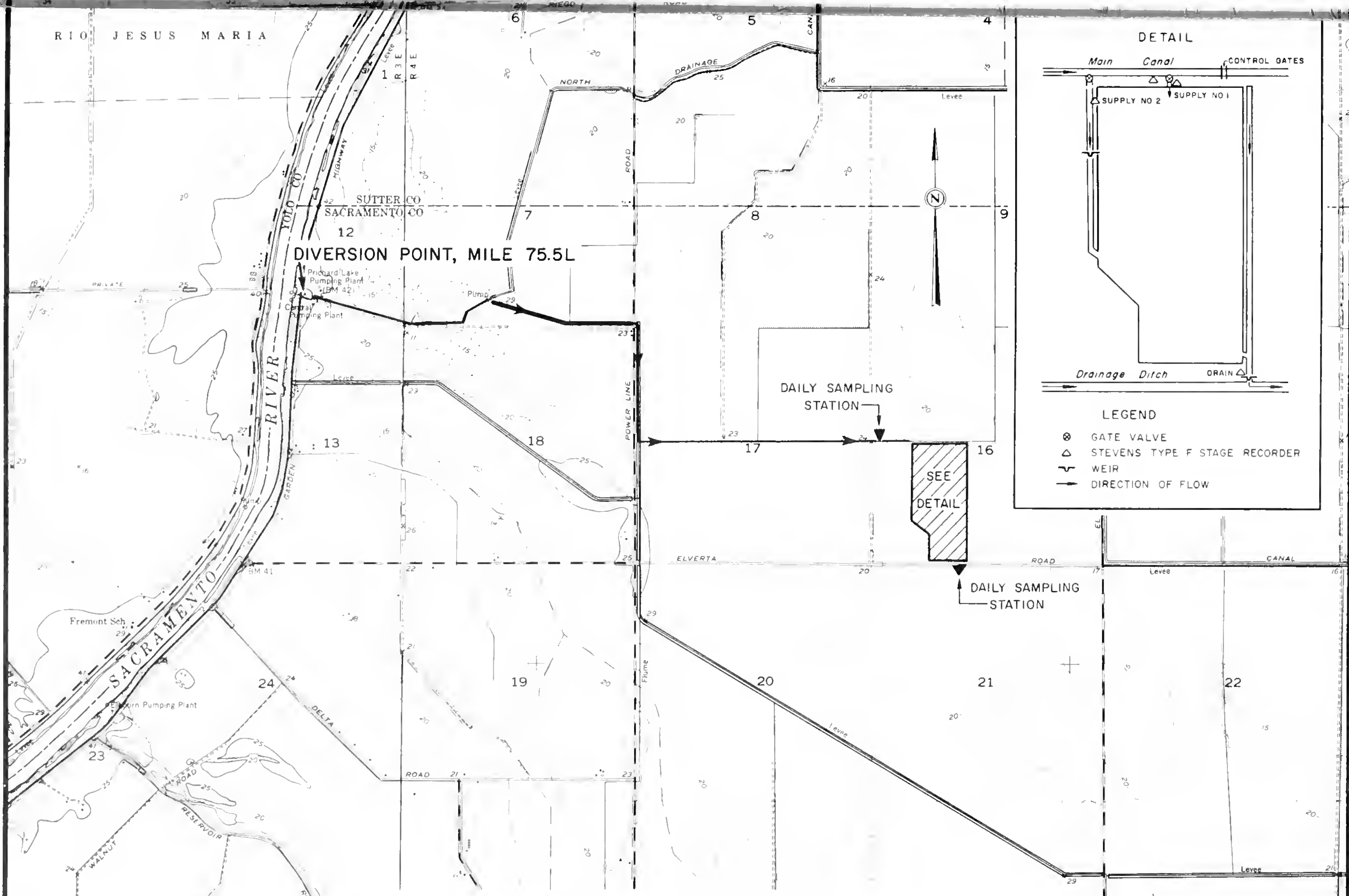


Figure 3.1. MAP OF SOPWITH RICE FIELD

September 2. Four days later, the levees were dynamited at selected points throughout the field to facilitate complete drainage.

Water Quality Changes

Daily samples were collected and analyzed to determine changes in specific conductance, temperature, dissolved oxygen, mineral constituents, and bacteriological quality during the rice growing period. Analytical results are listed in Table 3.5 through 3.8 and summarized in Figure 3.2.

The consumptive use of water by the rice is clearly indicated by the difference between supply and drain flows shown on Figure 3.2A. Nine and four tenths acre-feet per acre were applied, 5.3 were discharged. Assuming that the amount of water infiltrating through the hardpan was negligible, the balance of 4.1 acre-feet was lost to evaporation and transpiration.

Figure 3.2B shows specific conductance of supply and drainage waters. The higher values for the drain indicated the increase in dissolved minerals as the water passed through the field. Comparison with Figure 3.2A shows that conductance of the supply was inversely proportional to the flow up to about June 15. After that time the conductance increased slowly throughout the remainder of the season while the supply flows also increased. Conductance of the supply increased from about 140 to 300 micromhos during the season; corresponding concentrations of total dissolved solids (Table 3.5) were 82 and 200 ppm, respectively. Conductance of drainage waters showed less relationship with flow and was generally about 50 micromhos higher than that of the supply which was a calcium-magnesium bicarbonate water with about 28 percent sodium. The drainage water showed higher sulfate concentrations and sodium ratios, particularly in the early part of the season.

RESULTS OF ANALYSES

DAILY SAMPLING PROGRAM

RICE FIELD STUDY-RESULTS OF STANDARD MINERAL ANALYSES

1960-1961

Date Collected	4-25-60		5-2-60		7-14-60		4-25-60		5-2-60		7-14-60		9-6-60					
Time (P.S.T.)	1330		0755-1547 (Comp)		0750-1510 (Comp)		1500		0710-1523 (Comp)		0717-1440 (Comp)		1000					
Discharge, cfs-Mean Daily																		
Instantaneous																		
Temp. °F	61						71											
Dissolved Oxygen, ppm	11.0						5.6											
% Saturation	111						63											
pH Field Lab.		7.5		7.6		8.1		6.5		7.1		7.9		8.1				
EC x 10^6 at 25°C	139		186		268		200		172		297		342					
Constituents in	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)
Total Dissolved Solids																		
Sum	82		109		165		121		99		185		201					
Silica (SiO_2)	17		17		26		20		14		30		17					
Cations																		
Calcium (Ca)	11	0.55	13	0.65	18	0.90	4.8	0.24	7.3	0.36	21	1.05	22	1.10				
Magnesium (Mg)	4.7	0.39	6.9	0.57	12	1.02	4.4	0.36	4.9	0.40	15	1.25	17	1.38				
Sodium (Na)	7.4	0.32	12	0.52	18	0.78	26	1.13	18	0.78	20	0.87	26	1.14				
Potassium (K)	1.0	0.02	1.2	0.03	1.8	0.05	1.0	0.02	1.0	0.02	0.8	0.02	1.8	0.05				
Total Cations		1.28		1.77		2.75		1.75		1.56		3.19		3.67				
Anions																		
Carbonate (CO_3)	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00				
Bicarbonate (HCO_3)	57	0.93	77	1.26	125	2.05	45	0.74	63	1.03	164	2.69	166	2.72				
Sulfate (SO_4)	7.1	0.15	10	0.21	13	0.27	30	0.62	14	0.29	6.6	0.14	12	0.25				
Chloride (Cl)	5.4	0.15	11	0.31	14	0.39	12	0.34	8.6	0.24	10	0.28	23	0.65				
Fluoride (F)	0.0		0.1		0.2		0.1		0.2		0.2		0.1					
Nitrate (NO_3)	0.3		0.0		0.9		0.6		0.3		0.4		0.4					
Total Anions		1.23		1.78		2.73		1.71		1.57		3.13		3.63				
Boron (B)	0.03		0.09		0.11		0.11		0.05		0.09		0.15					
Total Hardness (As $CaCO_3$)	47		61		96		30		38		115		124					
NC Hardness	0		0		0		0		0		0		0					
Percent Sodium	25		29		28		64		50		27		31					
Color (Units)																		
Turbidity (Silica Scale)																		
Odor (Threshold) (60°C)																		
Nitrogen Series																		
Organic Nitrogen (N)																		
Nitrite (NO_2)																		
Nitrate (NO_3)																		
Ammonium (NH_4)																		
Phosphate - Ortho (PO_4)																		
Total (PO_4)																		
Ether Solubles																		
Biochemical Oxygen Demand (5-Day at 20°C)																		
Chemical Oxygen Demand																		
Suspended Solids																		
Detergents (ABS)																		
Phenolic Material																		
Settleable Solids (ml/l)																		

TABLE 3.6

SACRAMENTO RIVER WATER POLLUTION SURVEY

RESULTS OF ANALYSES

DAILY SAMPLING PROGRAM

RICE FIELD STUDY-SUPPLY WATERS

1960-1961

Date Collected	5/9-14/60		5/15-18/60		5/19/60		5/20/60		5/21/60		5/22-31/60	
Mean Discharge, cfs												
pH											8.2	
EC x 10^6 at 25°C	144		137		154		136		210		245	
Constituents in	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)
Total Dissolved Solids												
Sum											157	
Silica (SiO_2)											28	
Cations												
Calcium (Ca)											17	0.85
Magnesium (Mg)											9.8	0.81
Sodium (Na)	9.9	0.43	9.0	0.39	9.4	0.41	12	0.52	15	0.65	19	0.83
Potassium (K)											1.3	0.03
Total Cations												2.52
Anions												
Carbonate (CO_3)											0	0.00
Bicarbonate (HCO_3)											110	1.80
Sulfate (SO_4)											11	0.23
Chloride (Cl)	5.2	0.15	4.6	0.13	5.8	0.16	9.4	0.26	13	0.37	15	0.42
Fluoride (F)											0.1	0.00
Nitrate (NO_3)											1.8	0.03
Total Anions												2.48
Boron (B)	0.05		0.04		0.09		0.13		0.07		0.16	
Total Hardness (As $CaCO_3$)											83	
NC Hardness											0	
Percent Sodium											33	

Date Collected	6/1-2/60		6/3/60		6/4-9/60		6/10-15/60		6/16-18/60		6/19-23/60	
Mean Discharge, cfs												
pH												
EC x 10^6 at 25°C	180		123		160		207		250		210	
Constituents in	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)
Total Dissolved Solids												
Sum					107							
Silica (SiO_2)					24							
Cations												
Calcium (Ca)					15.0	0.75						
Magnesium (Mg)					5.0	0.41						
Sodium (Na)	12	0.52	7.6	0.33	10.0	0.44	13	0.56	16	0.70	15	0.65
Potassium (K)					1.1	0.03						
Total Cations						1.63						
Anions												
Carbonate (CO_3)					0	0.00						
Bicarbonate (HCO_3)					77	1.26						
Sulfate (SO_4)					5.4	0.11						
Chloride (Cl)	8.5	0.24	3.8	0.11	6.6	0.19	8.8	0.25	16	0.45	11	0.31
Fluoride (F)					0.0	0.00						
Nitrate (NO_3)					1.1	0.02						
Total Anions						1.58						
Boron (B)	0.09		0.04		0.08		0.13		0.12		0.11	
Total Hardness (As $CaCO_3$)					58							
NC Hardness					0							
Percent Sodium					27							

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
April 29		2.36		
30		2.19		
May 1		2.61		
2		2.98		
3		1.95		
4		1.59		
5		1.61		
6		1.77		
7		1.68		
8		1.74		
May 9	1310	1.86	68	147
10	0610	2.65	65	126
11	0645	2.55	66	161
12	0600	2.60	66	121
13	0615	2.58	64	166
14	0830	2.62	65	122
May 15	0810	2.94	66	139
16	0800	2.37	64	134
17	0630	1.94	64	133
18	0800	1.75	64	136
May 19	0640	1.61	63	156

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
May 20	0800	2.09	64	189
May 21	0545	1.59	63	214
May 22	0545	1.00	63	264
23	0700	1.22	60	242
24	----	1.05	--	---
25	0700	1.28	60	222
26	0630	1.11	63	243
27	0700	1.12	66	252
28	0700	1.03	68	226
29	0700	1.15	68	243
30	0700	1.33(est.)	69	262
31	0745	1.34	73	236

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
June 1	0630	0.97	73	184
2	0600	1.01	74	182
June 3	0700	1.55	73	126
June 4	0700	2.03	75	169
5	0630	2.29	73	150
6	0700	2.31	71	164
7	0700	2.31	70	151
8	0800	2.38	70	159
9	0730	2.43	70	162

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
June 10	0700	2.29	70	183
11	0700	2.22	72	199
12	0716	2.22	76	224
13	0600	2.00	76	226
14	0600	1.70	77	190
15	0600	1.62	78	215
June 16	0500	1.67	79	247
17	0900	1.78	79	259
18	0600	1.73	72	254
June 19	0700	1.78	73	204
20	0630	1.67	73	223
21	0600	1.83	70	217
22	0600	1.96	71	217
23	0830	1.84	80	213

SACRAMENTO RIVER WATER POLLUTION SURVEY

RESULTS OF ANALYSES

DAILY SAMPLING PROGRAM

RICE FIELD STUDY-SUPPLY WATERS

1960-1961

Date Collected	6/24-27/60		6/28-29/60		6/30-7/6/60		7/7-17/60		7/18-24/60		7/25-8/1/60	
Mean Discharge, cfs												
pH											8.3	
EC x 10^6 at 25°C	241		212		244		252		240		271	
Constituents in	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)
Total Dissolved Solids												
Sum											171	
Silica (SiO_2)											29	
Cations												
Calcium (Ca)											18	0.90
Magnesium (Mg)											13	1.04
Sodium (Na)	19	0.83	16	0.70	18	0.78	19	0.83	16	0.70	17	0.74
Potassium (K)											1.6	0.04
Total Cations												2.72
Anions												
Carbonate (CO_3)											0	0.00
Bicarbonate (HCO_3)											128	2.10
Sulfate (SO_4)											12	0.25
Chloride (Cl)	13	0.37	10	0.28	12	0.34	13	0.37	12	0.34	15	0.42
Fluoride (F)											0.1	0.00
Nitrate (NO_3)											1.8	0.03
Total Anions												2.80
Boron (B)	0.14		0.10		0.12		0.16		0.12		0.15	
Total Hardness (As $CaCO_3$)											97	
NC Hardness											0	
Percent Sodium											27	

Date Collected	8/1-3/60		8/4-8/60		8/9-13/60		8/14/60		8/17-23/60		8/24-9/2/60	
Mean Discharge, cfs												
pH											8.2	
EC x 10^6 at 25°C	242		292		281		290		291		311	
Constituents in	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)
Total Dissolved Solids												
Sum											200	
Silica (SiO_2)											33	
Cations												
Calcium (Ca)											20	1.00
Magnesium (Mg)											14	1.18
Sodium (Na)	15	0.65	20	0.87	19	0.83	22	0.96	21	0.91	24	1.04
Potassium (K)											1.9	0.05
Total Cations												3.27
Anions												
Carbonate (CO_3)											0	0.00
Bicarbonate (HCO_3)											147	2.41
Sulfate (SO_4)											14	0.29
Chloride (Cl)	13	0.37	18	0.51	16	0.45	17	0.48	17	0.48	18	0.51
Fluoride (F)											0.2	0.01
Nitrate (NO_3)											2.3	0.04
Total Anions												3.26
Boron (B)	0.14		0.13		0.18		0.05		0.07		0.15	
Total Hardness (As $CaCO_3$)											109	
NC Hardness											0	
Percent Sodium											32	

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
June 24	0830	1.82	74	235
25	0900	1.91	75	235
26	0700	1.65	71	238
27	0830	1.73	--	265
June 28	0730	1.76	70	203
29	0730	1.80	68	220
June 30	1900	1.72	76	257
July 1	0730	1.62	74	237
2	0730	1.72	73	236
3	0730	1.66	75	245
4	0800	1.72	76	237
5	0700	1.66	73	242
6	0805	1.67	73	236
July 7	0730	1.70	72	220
8	0740	1.86	73	252
9	0730	1.82	72	256
10	0715	1.76	69	230
11	0710	1.94	70	258
12	0705	2.10	70	251
13	0710	2.19	70	219
14	0710	1.87	73	277
15	0700	1.92	71	268
16	0700	1.82	74	253
17	1000	1.72	79	256

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
July 18	0900	1.75	80	227
19	0800	1.83	78	223
20	0615	1.77	76	225
21	0610	1.84	75	238
22	0606	1.90	76	248
23	0700	1.92	76	242
24	0830	1.89	76	247
July 25	0600	1.94	76	271
26	0600	1.98	74	262
27	0600	1.77	72	273
28	0605	1.71(est.)	74	262
29	0600	1.83(est.)	71	277
30	0800	1.70(est.)	72	272
31	----	1.70(est.)	--	---
Aug. 1	0530	1.53(est.)	69	273

* Mean daily flow.

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
Aug. 1	0830	1.53(est.)	72	247
2	0615	1.61(est.)	72	235
3	0830	1.32(est.)	73	228
Aug. 4	0700	1.33(est.)	74	267
4	1100	1.33(est.)	80	267
5	----	1.25(est.)	--	---
6	0815	1.64(est.)	74	267
7	0830	1.53(est.)	78	267
8	0700	1.37(est.)	73	265
Aug. 9	0625	2.12	76	278
10	0900	2.18	75	298
11	0730	1.91	73	273
12	0730	1.77	75	281
13	0830	1.76	76	285
Aug. 14	0500	1.90	71	285
14	0900	1.90	73	289

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
Aug. 17	0800	1.66	75	270
18	0830	1.96	78	287
19	0835	2.04	76	281
20	0725	1.72	73	289
21	0930	2.34	64	295
22	0730	1.93	69	307
23	0730	2.01(est.)	71	283
23	0830	2.01(est.)	75	278
Aug. 24	0830	2.55(est.)	69	298
25	0900	2.17(est.)	72	313
26	0945	1.31(est.)	71	314
27	----	1.72(est.)	--	---
28	0800	2.04(est.)	68	303
29	0910	2.55(est.)	66	307
30	0830	2.79	65	309
31	0700	2.74	68	285
Sept. 1	----	2.94	--	---
2	0700	2.44	68	298

* Mean daily flow.

TABLE 3.7

SACRAMENTO RIVER WATER POLLUTION SURVEY

RESULTS OF ANALYSES

DAILY SAMPLING PROGRAM

RICE FIELD STUDY-DRAIN WATERS

1960-1961

Date Collected												
Mean Discharge, cfs												
pH												
EC x 10^6 at 25°C												
Constituents in	mg/1 (ppm)	me/1 (epm)	mg/1 (ppm)	me/1 (epm)	mg/1 (ppm)	me/1 (epm)	mg/1 (ppm)	me/1 (epm)	mg/1 (ppm)	me/1 (epm)	mg/1 (ppm)	me/1 (epm)
Total Dissolved Solids												
Sum												
Silica (SiO_2)												
Cations												
Calcium (Ca)												
Magnesium (Mg)												
Sodium (Na)												
Potassium (K)												
Total Cations												
Anions												
Carbonate (CO_3)												
Bicarbonate (HCO_3)												
Sulfate (SO_4)												
Chloride (Cl)												
Fluoride (F)												
Nitrate (NO_3)												
Total Anions												
Boron (B)												
Total Hardness (As $CaCO_3$)												
NC Hardness												
Percent Sodium												

Date Collected							6/26-7/2/60		7/3-15/60		7/16-8/4/60	
Mean Discharge, cfs												
pH												
EC x 10^6 at 25°C							258		297		308	
Constituents in	mg/1 (ppm)	me/1 (epm)	mg/1 (ppm)	me/1 (epm)	mg/1 (ppm)	me/1 (epm)	mg/1 (ppm)	me/1 (epm)	mg/1 (ppm)	me/1 (epm)	mg/1 (ppm)	me/1 (epm)
Total Dissolved Solids												
Sum												
Silica (SiO_2)												
Cations												
Calcium (Ca)												
Magnesium (Mg)												
Sodium (Na)							22	0.96	23	1.00	27	1.17
Potassium (K)												
Total Cations												
Anions												
Carbonate (CO_3)												
Bicarbonate (HCO_3)												
Sulfate (SO_4)												
Chloride (Cl)							7.0	0.20	9.6	0.27	14	0.39
Fluoride (F)												
Nitrate (NO_3)												
Total Anions												
Boron (B)							0.13		0.09		0.14	
Total Hardness (As $CaCO_3$)												
NC Hardness												
Percent Sodium												

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
April 25	----	1.05(12H)	--	---
26	----	1.70	--	---
27	----	2.50	--	---
28	----	2.95	--	---
29	----	1.90	--	---
30	----	1.05	--	---
May 1	----	1.30	--	---
2	----	2.30	--	---
3	----	3.50(16H)	--	---
4	----	3.10	--	---
5	----	2.15	--	---
6	----	1.25	--	---
7	----	1.15	--	---
8	----	1.15	--	---
May 9	1300	0.95	81	235
10	0615	1.00	65	246
11	0620	1.15	67	255
12	0700	1.30	68	258
13	0620	1.20	62.5	260
14	0800	1.15	64	266
15	0800	0.95	69	292
16	0800	0.95	66	289
17	0630	1.10	63	278
18	0800	1.00	63	294
19	0640	1.40	58	285
20	0600	0.50	56	305

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
May 21	0600	0.40	61	305
22	0539	0.45	56	320
23	0700	0.45	56	320
24	0720	0.50	56	292
25	0700	0.80	60	256
26	0630	1.00	62	262
27	0700	0.75	66	276
28	0700	0.65	68	294
29	0800	0.50	67	311
30	0700	0.40	66	322
31	0746	0.40	75	311
June 1	0630	0.30	75	326
2	0545	0.20(21H)	72	327
3	0700	0.30	75	343
4	0630	0.40	73	370
5	0800	0.40(9H)	72	360
6	0632	0.35(17H)	67	364
7	0700	0.20	67	340
8	0800	0.60	69	291
9	0730	0.95	69	264
10	0700	1.30	70	257

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
June 11	0645	1.35	72	247
12	0700	1.35	77	247
13	0600	1.40(10H)	75	250
14	0600	1.40	76	257
15	0645	1.35	79	262
16	0500	1.30	79	260
17	0900	1.15	75	259
18	0600	1.05	69	271
19	0700	1.05	70	272
20	0630	1.00	71	271
June 21	0630	0.90	67	265
22	0700	0.90	71	261
23	0845	1.00	79	259
24	0700	1.15	73	259
25	0900	1.20	74	266
June 26	0730	1.30	70	273
27	0800	1.30	73	279
28	0730	1.25	70	280
29	0730	1.20	67	282
30	0715	1.15	79	269
July 1	0745	1.15	76	268
2	0745	1.15	73	277

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
July 3	0745	1.10	76	286
4	0800	1.05	76	290
5	0730	1.05(18H)	71	290
6	0800	1.00	74	290
7	0710	1.00(Inst.)	72	293
8	0735	1.00	73	302
9	0700	1.00	71	301
10	0710	1.00	67	293
11	0715	1.00	67	294
12	0700	0.90	69	301
13	0700	0.90	69	298
14	0700	0.90	71	300
15	0700	0.90	70	297
July 16	0700	0.90	72	319
17	1000	0.90	79	324
18	0900	0.90	76	330
19	0800	0.90	76	332
20	0600	0.90	78	330
21	0600	0.90	74	330
22	0605	0.90	75	327
23	0630	0.90	72	323
24	0830	0.90(15H)	75	333
25	0600	0.90	72	317
26	0600	0.90	73	320
27	0605	1.00	71	325
28	0600	1.05	72	332
29	0545	1.10	70	331
30	0800	1.10	69	332
31	----	1.05	--	---
Aug. 1	0545	0.90	67	333
1	0835	0.90	66	333
2	0830	0.90	--	337
3	0900	0.90	69	337
4	0700	0.90	68	328
4	1100	0.90	77	[illegible]

TABLE 37

SACRAMENTO RIVER WATER POLLUTION SURVEY

RESULTS OF ANALYSES

DAILY SAMPLING PROGRAM

RICE FIELD STUDY-DRAIN WATERS

1960-1961

Date Collected	8/6-13/60		8/14-23/60		8/24-25,8/29-9/3/60		9/4-6/60		9/7-9/60			
Mean Discharge, cfs												
pH	7.8								8.3			
EC x 10^6 at 25°C	345		370		352		342		390			
Constituents in	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)	mg/l (ppm)	me/l (epm)
Total Dissolved Solids												
Sum	202								225			
Silica (SiO_2)	16								15			
Cations												
Calcium (Ca)	23	1.15							24	1.20		
Magnesium (Mg)	17	1.43							19	1.56		
Sodium (Na)	28	1.22	37	1.61	29	1.26	27	1.17	32	1.39		
Potassium (K)	1.0	0.02							2.1	0.05		
Total Cations		3.82								4.20		
Anions												
Carbonate (CO_3)	0	0.00							0	0.00		
Bicarbonate (HCO_3)	183	3.00							197	3.23		
Sulfate (SO_4)	4.4	0.09							10	0.21		
Chloride (Cl)	20	0.56	21	0.59	22	0.62	22	0.62	25	0.70		
Fluoride (F)	0.2	0.01							0.2	0.01		
Nitrate (NO_3)	1.0	0.02							0.9	0.01		
Total Anions		3.68								4.16		
Boron (B)	0.15		0.15		0.13		0.11		0.13			
Total Hardness (As $CaCO_3$)	129								138			
NC Hardness	0								0			
Percent Sodium	32								33			

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
Aug. 5	Not	sampled		
Aug. 6	0820	0.75	69	338
7	0800	0.70	75	344
8	0730	0.60	68	339
9	0630	0.60	74	345
10	0900	0.60	71	349
11	0700	0.70	68	350
12	0800	0.85	70	351
13	0835	1.00	74	348
Aug. 14	0500	1.00	65	355
14	0905	1.00	70	348
15	----	0.90	--	---
16	0800	0.90	70	345
17	0815	1.00	69	347
18	0840	1.10	70	350
19	0840	1.10	70	349
20	0740	1.10	69	350
21	----	1.15	--	---
22	0800	1.10	65	350
23	0630	1.10	64	348

* Mean daily flow.

Date	Time PST	Flow* cfs	Temp. °F	Specific Conductance
Aug. 24	0845	1.15	65	340
25	0910	1.15	64	342
26	Not	sampled		
27	Not	sampled		
28	Not	sampled		
29	0905	1.05	62	339
30	0830	0.85	64	351
31	0700	0.90	63	345
Sept. 1	0700	1.05	64	331
2	0700	1.10	64	341
3	0730	1.75	65	338
Sept. 4	0800	2.30	68	334
5	0830	2.15	60	330
6	0730	1.80	62	331
Sept. 7	0800	1.00	62	350
8	0830	0.40	63	379
9	0800	0.20	67	415

TABLE 38

SACRAMENTO RIVER WATER POLLUTION SURVEY

RESULTS OF ANALYSES

DAILY SAMPLING PROGRAM

RICE FIELD STUDY-DUIRNAL VARIATIONS OF TEMPERATURE AND DISSOLVED OXYGEN

1960-1961

SUPPLY

Date	Time PST	Temp. °F	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	$ECx10^6$ at 25°C	5-Day BOD ppm	pH	Coliform MPN/100 ml
5/2	0755	60.0	7.6	76	178			2,300
	0902	60.5	7.8	78	180			1,200
	0955	62.5	8.1	83	179			6,200
	1045	63.0	8.4	86	177			<600
	1315	65.0	9.8	104	173			5,000
	1402	65.5	10.2	108	171			6,200
	1455	66.0	10.7	114	173			6,200
	1547	66.0	10.9	116	173			2,300
7/14	0750	72	6.7	76	257		7.2	
	0900	73	7.2	83	262		7.3	
	1002	75	7.3	85	267		7.2	
	1127	76	7.7	91	261		7.2	
	1232	77	8.2	98	270		7.3	
	1330	78	8.5	102	267		7.4	
	1420	79	8.5	104	265		7.3	
	1510	79	8.7	106	269		7.1	
8/11	0315	73	9.8*	112*	278	0.74		
	0400	73	7.3	84	278	0.78		
	0500	73	7.1	81	279	0.84		
	0600	73	6.8	78	275	1.32		
	0700	73	6.9	79	275	0.81		
	0800	72.5	7.5	86	269	1.66		
	0900	73	7.7	88	274	0.76		
	1000	74	7.9	91	268	1.01		
	1100	75	8.0	94	269	1.02		
	1200	76	8.3	98	266	1.25		
	1325	77.5	9.0	108	270	1.54		
	1430	77.5	8.8	106	269	1.26		
	1530	78.0	9.1	110	269	1.16		
	1625	78	8.7	105	267	1.14		
	1720	77.5	8.7	104	267	1.04		
	1820	77	8.1	97	267	1.68		
	1930	76	7.7	91	267	2.32		
	2020	76	7.6	90	266	3.11		
	2120	75	7.8	91	272	1.00		
	2220	75	7.9	92	274	0.99		
	2325	74.5	7.9	92	274	0.91		
8/12	0023	74.5	7.7	90	275	1.39		
	0120	74.0	7.6	88	275	0.97		
	0220	74.0	7.6	88	277	0.97		
	0320	74.0	7.6	88	277	0.92		

* Questionable value.

DRAIN

Date	Time PST	Temp. °F	Dissolved Oxygen ppm	Dissolved Oxygen % Sat.	$ECx10^6$ at 25°C	5-Day BOD ppm	pH	Coliform MPN/100 ml
5/2	0710	59.5	8.2	81	164			2,300
	0833	60.0	8.4	83	162			2,300
	0928	63.0	8.6	88	161			2,300
	1022	65.0	8.9	94	163			2,300
	1245	72.0	9.2	104	163			2,300
	1340	73.5	9.4	108	161			600
	1427	75.0	9.5	111	159			6,200
	1523	75.0	9.5	111	158			2,300
7/14	0717	71	3.5	39	294		6.8	
	0830	72	4.8	55	296		6.9	
	0943	74	6.3	73	297		6.9	
	1048	77	7.6	91	298		7.0	
	1205	79	8.8	107	297		7.0	
	1300	80	9.6	118	295		7.0	
	1350	81	9.9	123	293		7.1	
	1440	81	9.7	121	296		7.1	
8/11	0315	68	3.1	34	375	0.73		
	0415	68	3.5	38	354	0.43		
	0515	67	3.7	40	350	0.52		
	0615	66.5	3.8	40	352	0.62		
	0715	67	4.2	45	350	0.49		
	0830	68.5	4.9	54	345	0.57		
	0930	70	5.9	65	354	0.50		
	1030	73	7.0	80	346	0.58		
	1130	75	8.0	93	346	0.59		
	1310	77.5	9.6	115	344	0.57		
	1400	77.5	9.3	112	335	0.69		
	1445	77.5	8.7	104	340	0.73		
	1515	77.5	9.2	110	341	0.63		
	1550	77.5	9.2	110	345	0.69		
	1645	77	7.7	92	358	0.65		
	1650	77.5	8.1	97				
	1745	77	7.0	83	339	0.63		
	1750	77	6.4	76				
	1840	76.5	5.7	66	340	0.62		
	1855	76	5.5	65				
	1945	75	5.4	62	341	0.67		
	2055	74	4.4	51	341	0.54		
	2140	73.5	4.2	48	336	0.58		
	2200	73	4.0	45				
	2245	73	4.5	52	339	0.83		
	2300	72.5	4.1	47				
	2345	72	3.7	42	338	0.51		
8/12	0050	72.0	3.6	41	341	0.59		
	0145	71.0	3.6	40	341	0.57		

RICE FIELD STUDY
ALGAE IN SOPWITH FIELD, AUGUST 12, 1960

SUPPLY

Predominant Group - Filamentous Greens
Predominant Genera - Oedogonium

Coccoid Blue-Greens
- Anacystis

Filamentous Blue-Greens
- Anabaena*
- Calothrix*
- Cylindrospermum
- Gleotrichia*
- Nodularia*
- Nostoc
- Oscillatoria

Coccoid Greens
- Ankistrodesmus
- Closterium
- Closteriopsis
- Coelastrum
- Cosmarium
- Crucegenia
- Dictosphaerum
- Dimorphococcus
- Eudorina
- Gloeocystis
- Onychonema
- Oocystis
- Pediastrum
- Plenotaenaium
- Scenedesmus
- Sphaerocystis
- Straurastrum
- Tetrahedron
- Trochiscia

Filamentous Greens
- Mougeotia
- Oedogonium**
- Spirogyra

Pigmented Flagellates
- Euglena
- Phacus
- Trachelamonas

Centric Diatoms
- Cyclotella
- Stephanodiscus

Pennate Diatoms
- Cymbella
- Fragilaria
- Navicula
- Nitzschia
- Rhopalodia
- Synedra

Protozoa
- Actinophrys
- Arcella
- Aspidisca
- Centropysix
- Diffugia
- Paramecium

Macroplankton
- Rotifers
- Nematodes
- Tardigrada (little water bears)
- Gladocera (water flees)
- Acari (water mites)
- Gastrotricha

CENTER OF FIELD

Predominant Group - Filamentous Blue-Greens
Predominant Genera - (a) Anabaena
(b) Gleotrichia
(c) Nodularia

Coccoid Blue-Greens
- Anacystis

Filamentous Blue-Greens
- Anabaena*
- Aphanizomenon
- Cylindrospermum
- Gleotrichia**
- Nodularia*
- Oscillatoria
- Phormidium
- Rivularia

Coccoid Greens
- Ankistrodesmus
- Closterium
- Closteriopsis
- Coelastrum
- Cosmarium
- Crucegenia
- Dictyosphaerum
- Dimorphococcus
- Hydrodicton
- Oocystis
- Ophiocytium
- Pediastrum
- Scenedesmus
- Selenastrum
- Sorastrum
- Staurastrum

Filamentous Greens
- Mougeotia
- Oedogonium**
- Spirogyra
- Zygnema

Pigmented Flagellates
- Euglena
- Phacus
- Trachelamonas

Centric Diatoms

Pennate Diatoms
- Cymbella
- Navicula
- Strauroneis

Protozoa
- Actinophrys
- Aspidisca
- Diffugia
- Lacrymaria
- Paramecium

Macroplankton
- Acari (water mite)
- Gastrotricha
- Nematodes
- Rotifers

DRAIN

Predominant Group - Filamentous Greens
Predominant Genera - Oedogonium

Coccoid Blue-Greens
- Anacystis

Filamentous Blue-Greens
- Anabaena
- Calothrix
- Cylindrospermum**
- Gleotrichia*
- Oscillatoria*
- Rivularia*
- Spirulina

Coccoid Greens
- Ankistrodesmus
- Cosmarium
- Desmidium
- Dimorphococcus
- Hyalotheca
- Onychonema
- Pediastrum
- Pleurotaenium
- Radiofilum
- Scenedesmus
- Selenastrum
- Sorastrum
- Straurastrum
- Xanthidium

Filamentous Greens
- Microspora
- Oedogonium**
- Spirogyra
- Zygnema

Pigmented Flagellates
- Peridinium
- Lepocinclis
- Phacus

Centric Diatoms
- Cyclotella
- Melosira
- Stephanodiscus

Pennate Diatoms
- Amphicampa eruca
- Amphora
- Bacillaria
- Fragilaria
- Frustulia
- Navicula
- Nitzschia
- Rhopalodia*
- Synedra

Protozoa
- Arcella
- Aspidisca
- Diffugia*
- Paramecium

Macroplankton
- Nematodes
- Rotifers

---

* Large numbers.
** Predominant.

Note: Names listed alphabetically within classification groups without regard to numbers. Classification to genus type.

Figure 3.2C shows the daily quantities of salts entering and leaving the rice field during the growing season estimated from data in Tables 3.5, 3.6, and 3.7. The total amounts of salts applied to and draining from the field were 97 and 68 tons, respectively. Some of the difference of 29 tons was harvested, but most of it remained on the field. Undoubtedly, much of the remaining salts was removed by lateral movement to the drainage ditch, losses from the No. 2 supply ditch, deep percolation, and flushing by the following winter rains. Additional data are required to determine the relative importance of these factors.

Daytime water temperatures in the supply and drain (Tables 3.6 and 3.7) were similar, and exceeded the apparently critical value of 65°F from the end of May to the middle of September.

Biological and Bacteriological Aspects

Figures 3.2D, E, and F show diurnal variations of temperature and dissolved oxygen. Photosynthetic activity and respiration (see Chapter V, Appendix B) were high in the field, although it is not possible to separate the effects of the rice from those of plankton. The large variations of temperature, as compared to variations in streams, reflect the efficiency of solar heating in shallow water.

The bacteriological quality of the supply and drain waters were similar (Table 3.8). A limited study of total coliform and fecal coliform concentrations is summarized on Figure 3.3. The significance of bacteriological observations is discussed in Chapter V, Appendix C.

Table 3.9 indicates that plankton found in the rice field differ significantly from those in the Sacramento River (Chapter VI, Appendix C). Filamentous green and blue-green algae dominated whereas, in the river, diatoms were the most important.

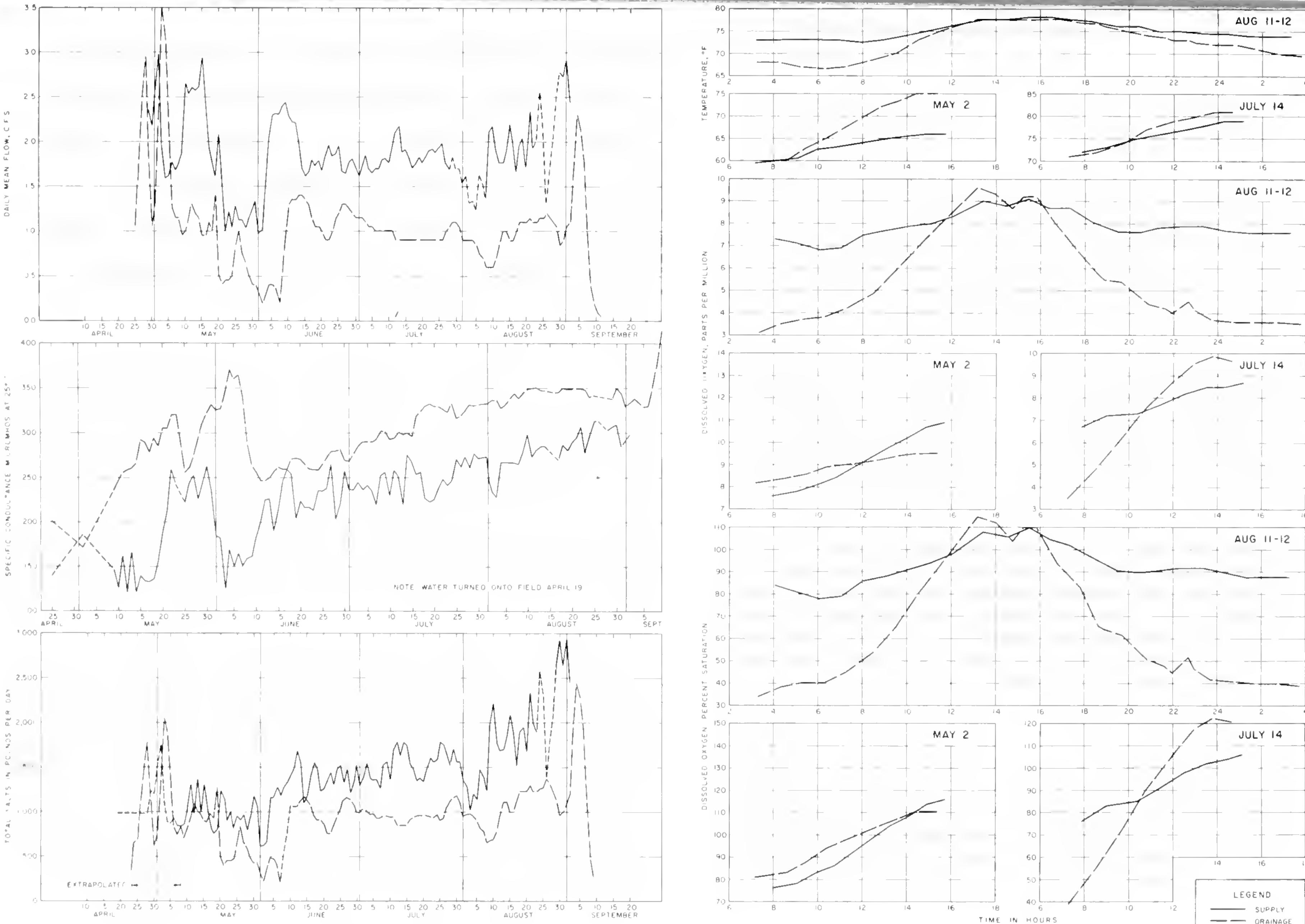
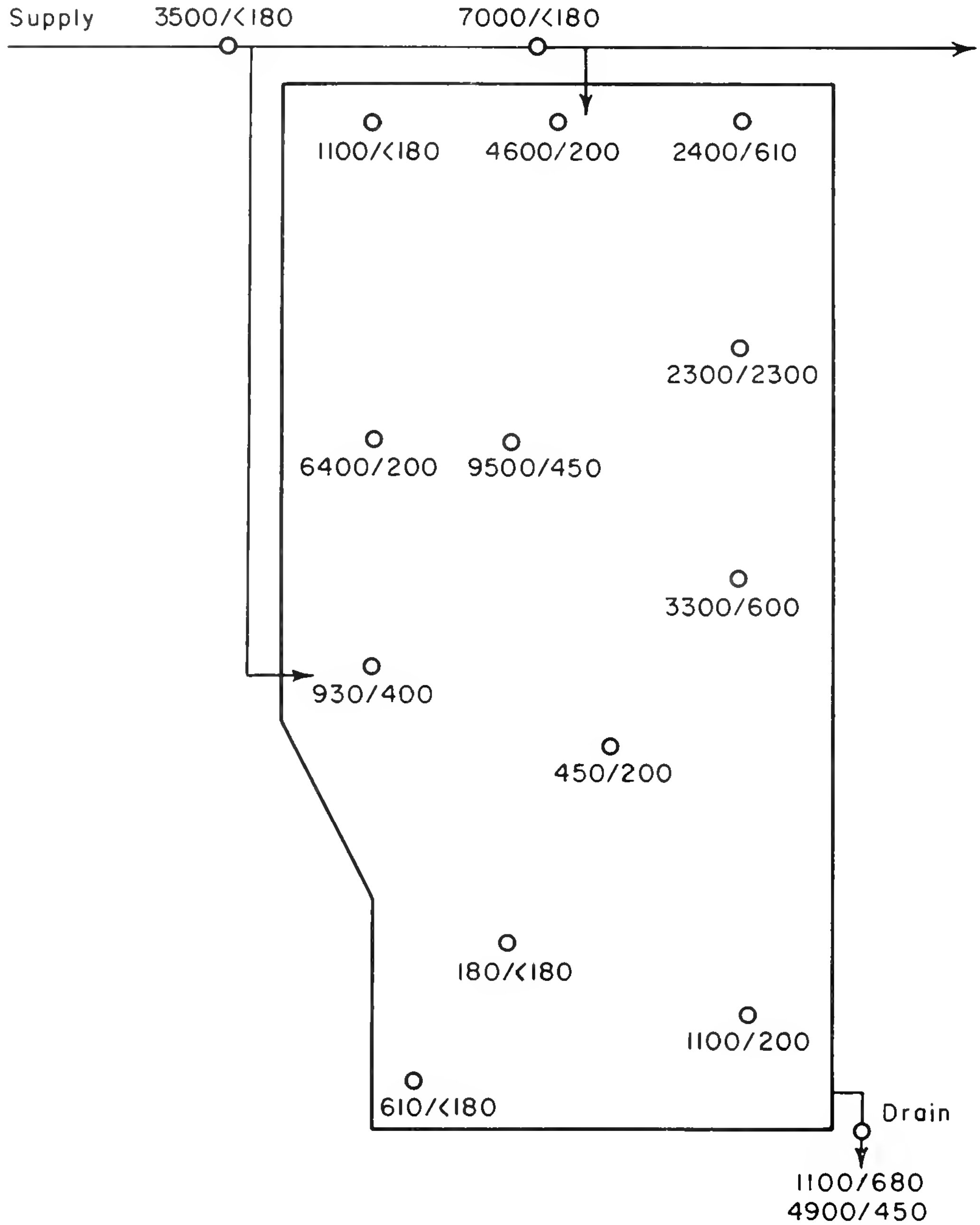


Figure 3.2. RICE FIELD STUDY - WATER QUALITY CHANGES 1960



COLIFORM/FECAL COLIFORM (MPN PER 100 ml.)

Figure 3.3. BACTERIOLOGICAL QUALITY OF RICE FIELD WATER
AUGUST 12, 1960

Effects of Weedicide Application

A special study was made of the effects of a weedicide on water quality.

On June 22, 1960, the field was sprayed by airplane with MCPA (2-methyl, 4-chlorophenoxyacetic acid) at a rate of 12 ounces per acre in order to control broad leaf weed. The field was flooded to an average depth of about four inches at the time. The resulting initial concentration of MCPA was accordingly about one ppm.

Between June 24 and July 4, 1960, a sample was taken by the carbon adsorption method (Chapter III, Appendix C) by passing 5,460 gallons of drainage water through the filter. Analysis of the sample showed an average of one part per billion of MCPA in the drainage water. Although the initial concentration of the weedicide was probably higher, small and apparently healthy fish were observed in the drain throughout the sampling period.

Irrigation Drainage Study

A study was made of water quality in major irrigation drains in the Sacramento Valley. Discussion of the effects of drainage upon the Sacramento River and the basic data are included in Appendix B. In general, it was found that the electrical conductance of drainage waters was from 300 to 600 micromhos during the irrigation season and from 600 to 1200 during the winter, depending upon the particular area.

A special effort was made to determine water quality changes during the irrigation season in Reclamation District 108. This district occupies about 45,000 acres in the area between the Sacramento River and the Colusa Basin Drainage Canal, and extends from Grimes to about mile 100 on the river (Plate 1). An estimated 85 percent of the water demand

is diverted from the river at Wilkins Slough (mile 118) and the balance comes from the Back Borrow Pit bordering the Colusa Basin Drainage Canal and from local ground water supplies. Sacramento River water supplied to the district had an average conductivity of about 140 micromhos, about 0.1 ppm boron, 9 ppm sodium, and 4 ppm chloride.

All of the drainage from the district is collected in surface drains which lead to a pumping plant at mile 100.1R (Plate 1). The drainage waters had an average conductivity of about 550 micromhos, 0.4 ppm boron, 65 ppm sodium, and 35 ppm chloride.

The increases in mineral concentrations cannot be explained by consumptive use, and suggest that either there is a large amount of leaching from the soil or there are local sources of highly mineralized ground water. Since the district has been farmed for many years, it is not likely that leaching can account for increases. The limited data from the department's ground water monitoring program do not show that the shallow ground water, which provides an estimated 3 to 5 percent of the demand, is unusually mineralized; for this source to account for the increase in boron, from 3 to 5 ppm are required in the water. The mineralized waters may come from deep ground waters as a result of exploration and development of oil and natural gas in the area. The available data do not permit evaluation of the several possibilities, and they preclude computations of salt-balances for the district.

CHAPTER V. INDUSTRIAL WATER SUPPLY

The major industrial use of water in the Sacramento River is for power generation. The Central Valley Project's Shasta and Keswick power plants have an installed capacity of 454,000 kilowatts and utilize 5,915,000 acre-feet of water per year. Power generation itself is a non-consumptive use of water which requires regulation of reservoir releases in accordance with power demands. The effects of fluctuating releases upon river flows is minimized by controlled releases from afterbay storage.

The processing of forest products is important throughout the Sacramento Valley. Sacramento River water is used directly for these purposes in the Redding - Red Bluff area. Water requirements for pulp and paper processing are large and the treatment and disposal of the liquid wastes is a problem of national importance. Present discharges have not resulted in serious degradation (see Chapter VII of this appendix).

Most of the industrial water requirements along the Sacramento River are met by municipal water supply systems. These are typically seasonal demands involved in processing agricultural products which result in widely varying discharge quantities and qualities of the municipal sewage treatment plants (Chapter VII).

A large amount of Sacramento River water is used industrially in the western portion of the Sacramento-San Joaquin Delta. Since these installations are not along the main stem of the river, water requirements and waste disposal problems associated therewith are beyond the purview of the present investigation.

CHAPTER VI. RECREATION

A number of recreational activities can be encompassed by the term "boating". These activities extend from the more strenuous, such as speed-boat racing, to the more leisurely boat fishing and cruising. Camping on the river banks which is associated with boating and extended living in cabin boats is common.

Other recreational activities such as swimming, wading, and water-skiing are collectively considered as water-contact sports. Because of the public health significance of water-contact sports, the discussion of these activities has been included in Chapter V, Appendix C.

The Sacramento River is ideally suited for pleasure boating and boat fishing. A channel has been dredged upstream to Colusa which will accommodate large boats and small boats can navigate throughout the river. Fishing boats can be rented or launched in almost every section of the river. There are approximately 68 public landings, parks, resorts and harbors that provide boating and fishing facilities and may offer overnight accommodations. There are long stretches where the tree-lined river passes through primitive areas adding to the esthetic enjoyment of boating.

In addition to individual boating activities, there is an annual speedboat race from Stockton to Colusa. Boating regattas are held at Sacramento and other localities, and river cruises are made by groups of boating enthusiasts.

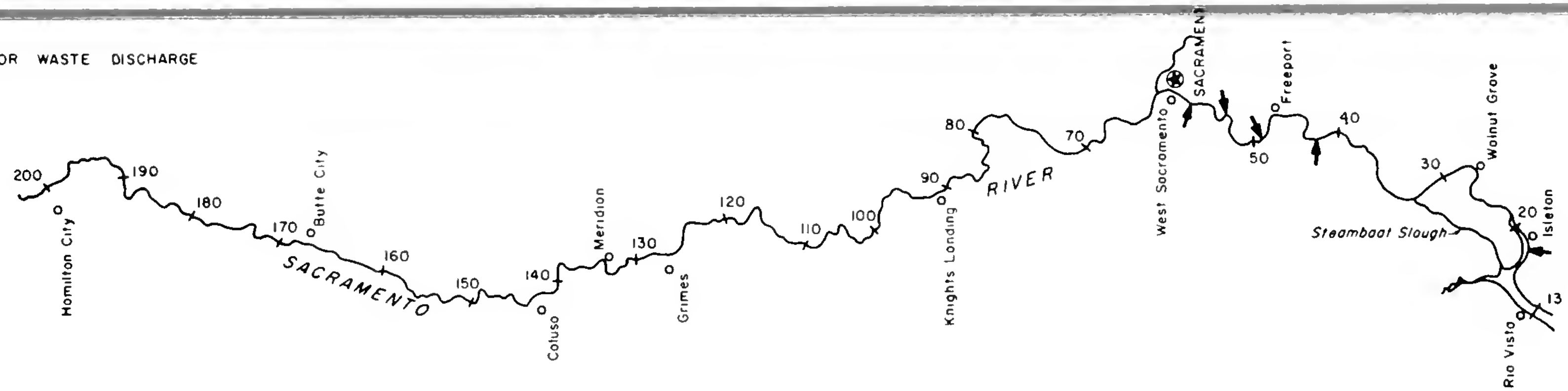
Downstream from Sacramento, floating restaurants with docking facilities are available for public use. At Walnut Grove, new docking facilities are being constructed to serve the boating public at a recently renovated hotel and restaurant. Large marinas at Rio Vista and near

Isleton have recently expanded their facilities, and a new, large park and marina is planned north of Colusa.

A survey of recreational activities on the river between Hamilton City and Rio Vista, including Steamboat Slough between Courtland and Rio Vista, was made by boat on Labor Day weekend, September 3 - 5, 1960. The results of this survey are summarized on Figure 3.4. A total of 2,338 people was observed. This integrates individual observations along the river, and may be assumed to reflect instantaneous daytime recreational activity. The actual number of people who used the river was undoubtedly several times greater as indicated by the ratio of total boats (2,584) to boats in use (628). It is not possible to estimate the additional number of boats which were launched from trailers during the weekend but which were not observed. A total of 43 resorts, public landings, camping areas and parks were observed. There were 90 private docks, fishing floats and boat sheds.

Information on boating activities from Anderson to Butte City was obtained from surveys made by the State Department of Public Health in 1956 and 1960. In these surveys information on the uses of the river was obtained from resort owners along the river. The findings of these surveys are summarized in Table 3.10 which lists the maximum of persons and boats for a single day during the recreational season. It can be seen that the number of privately owned boats berthed at the resorts or launched from trailers almost doubled during the four-year period. The number of persons boating and fishing from boats increased proportionally.

→ INDICATES MAJOR WASTE DISCHARGE



RIVER MILES

	200–190	190–180	180–170	170–160	160–150	150–140	140–130	130–120	120–110	110–100	100–90	90–80	80–70	70–60	60–50	50–40	40–30	30–20	20–13
BOATS																			
ANCHORED	123	2	23	40	39	41	112	73	2	7	3	6	140	132	703	160	119	90	139
PLEASURE	5	4	0	0	1	7	4	4	1	5	7	6	31	29	113	16	40	59	57
FISHING	7	4	3	0	7	17	50	24	6	1	4	1	17	7	33	20	7	4	29
TOTAL BOATS	135	10	26	40	47	65	164	101	9	13	14	13	188	168	849	196	166	153	225
PEOPLE																			
FISHERMEN																			
BOAT	11	7	7	0	18	37	114	45	13	2	13	1	28	15	67	42	12	6	66
BANK	12	3	13	0	0	0	9	0	2	0	18	10	29	47	23	43	25	34	62
(Total)	(23)	(10)	(20)	(0)	(18)	(37)	(123)	(45)	(15)	(2)	(31)	(11)	(57)	(62)	(90)	(85)	(37)	(40)	(128)
BOATERS	9	10	0	0	3	14	5	9	2	20	25	9	107	102	401	46	134	173	175
SKIERS	0	0	0	0	0	0	0	0	0	0	3	4	3	5	10	0	4	19	24
SWIMMERS	0	0	0	0	0	0	0	0	0	0	0	0	5	0	4	1	1	5	30
WADERS	1	0	0	0	0	0	0	0	0	0	3	0	11	6	18	19	15	14	58
(Total Water Contact Sports)	(1)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(6)	(4)	(19)	(11)	(32)	(20)	(20)	(38)	(112)
TOTAL PEOPLE	33	20	20	0	18	51	128	54	17	22	62	24	183	175	523	151	191	251	415

Figure 3.4. RECREATIONAL USE OF SACRAMENTO RIVER
Hamilton City to Rio Vista
September 3–5, 1960

Table 3.10

BOATING FROM ANDERSON TO BUTTE CITY, 1956-1960

	October 1956	September 1960
Number of Resorts	22 + 1 county park	21 + 4 county park
Rental Boats	145	91
Private Boats (moored)	485	764
Private Boats (launched)	150	384
Persons Fishing From Boats)	) 1,075	1,492
Persons Pleasure Boating)		407

CHAPTER VII. FISH AND WILDLIFE

Sacramento River water provides for large numbers of migratory and resident fish and wildlife. The anadromous fish of the river and the migratory waterfowl of the Pacific Flyway are of major economic importance to all the States of the Pacific Coast. These renewable resources are dependent upon both the quantity and quality of the water which are provided by natural and regulated flows and by requirements for and monitoring of waste discharges into the river.

An important commercial fishery depends on the king salmon of the Sacramento River. This is an anadromous species which is hatched in upstream reaches, spends a month or two growing in the river, attains adulthood in about four years in the ocean, and returns to the river to spawn and die. The estimated contribution of the Sacramento and San Joaquin Basins to the California king salmon fishery from 1948 to 1959 was 5,800,000 pounds retailing at approximately $3,600,000 annually. Moreover, king salmon from these basins contribute an appreciable but unknown amount to the Oregon and Washington commercial fisheries.

The total value of the sport fisheries for species that are dependent upon Sacramento River water is not measureable at this time. Both economic and aesthetic benefits are attributable to these fisheries. Dollar values cannot be applied to aesthetic benefits, although it is recognized that such benefits are highly valuable to the people of the State.

An indication of the economic value of the sport fisheries is given by gross annual expenditures by anglers pursuing their sport. The California Department of Fish and Game estimated that anglers spent about $26,000,000 in 1953 fishing for king salmon, steelhead, and striped bass

in the Sacramento and San Joaquin Basins. Undetermined expenditures were made in connection with fishing for American shad, white catfish, channel catfish, black bass, and panfish. Current expenditures are not known, but they are certainly greater than the 1953 amounts.

Many thousands of acres, both riparian and agricultural lands in the Sacramento Valley provide habitat for wildlife. For example, Colusa, Sutter, and Butte Basins, provide wintering areas for five to eight million waterfowl that frequent the Pacific Flyway, a migration path which extends along the western part of North America and funnels through the Central Valley of California. These lands also provide considerable habitat for pheasants.

Sacramento River water is essential to the maintenance of the above fish and wildlife populations and reservoir releases have been established for this purpose. Minimum fish releases from Shasta Dam provide from 2,300 to 3,900 cfs, depending on the season, during normal years and from 2,000 to 2,800 cfs during critical years. Minimum releases from Folsom Dam assure 500 cfs in the American River during the spawning season and 250 cfs throughout the rest of the year. Other diversions of Sacramento River water through the Delta-Mendota Canal are made in the fall for wildfowl habitat in the San Joaquin Valley grasslands.

CHAPTER VIII. NAVIGATION

The Sacramento River channel is maintained at minimum depths of 10 feet from the Delta to the City of Sacramento and six feet between Sacramento and Colusa. These depths are provided by maintaining a minimum stream flow of 5,000 cfs at the navigation control point near Wilkins Slough.

An estimated 5,550,000 tons of commercial products, consisting primarily of petroleum products with a lesser, though significant, quantity of farm produce, were shipped through the Sacramento River's navigation system in 1960. There is also a large amount of military shipping.

Under future conditions, the minimum flow at the navigation control point will be 4,000 cfs with an allowable depletion of 1,000 cfs downstream from the control point during the irrigation season.

By 1990, commercial shipping in the Sacramento River area is expected to be about two and one-half times that of 1960. Estimated tonnage of commercial shipping for the period 1960 to 1990 is tabulated below. Military shipments are not included. Petroleum will remain the principal commodity to be shipped.

SACRAMENTO RIVER COMMERCE

Year	Millions of Tons of Products
1960	5.55
1970	7.78
1980	10.74
1990	14.63

Presently under construction and anticipated to increase river commerce projections, is the Sacramento Deep Water Channel and terminal facilities at Sacramento. The channel, some 30 miles in length, will connect Cache Slough with a turning basin in West Sacramento. At low tide the ship channel will be 30 feet deep, with a 200 feet bottom width.

CHAPTER IX. WASTE DISPOSAL

A major use of the Sacramento River is for the disposal of wastes. The history and public health benefits of water-borne waste collection and treatment works are well known. Local physiographic land-use and economic considerations have resulted in ultimate disposal of these wastes to water courses. The effects of waste disposal on the Sacramento River are discussed in Appendix B. Pertinent data on individual waste collection, treatment, and disposal works are presented on the following pages.

Domestic and Municipal Wastes

In the early 1900's numerous communities discharged raw sewage or septic tank effluent into the Sacramento River. For the most part, the communities and their waste discharges were small, and dilution and self-purification characteristics of the river were thought to be adequate in most areas to prevent adverse water quality conditions. The reach of the river below the City of Sacramento was one area where it was evident even in these early times that dilution alone could not cope with the amount of raw sewage entering the river. As a result of cases of typhoid fever caused by the ingestion of untreated river water in this area, warning signs were posted along the river in 1915 declaring that untreated river water was unfit for swimming, vegetable washing and domestic purposes.

The increased use of the river for irrigation, recreation, and domestic water eventually resulted in a need for sewage treatment facilities for the sewage discharges in all sections of the river. Although planning and construction of treatment facilities were retarded by the wartime restrictions of World War II, primary sewage treatment facilities were constructed at all the major sewage discharges to the river within

Table 3.11

SEWAGE DISCHARGES TO THE SACRAMENTO RIVER

Redding	1890-1930	Alternately land disposal to a sewage farm and direct discharge to river.
	1930-1948	Raw sewage discharge to river.
	1948-	Primary treatment. Effluent discharged to river.
Anderson	1930-1949	Individual septic tank systems with occasional overflow to river.
	1949-1958	Primary treatment (Imhoff Tank). Ponds added about 1950. Occasional bypass to river.
	1958-	Additional ponds constructed. No discharge to river.
Red Bluff	1898-1940	Three raw sewage discharge to river.
	1940-1952	One raw sewage discharge south of town.
	1952-	Primary treatment. Effluent discharged to river.
Corning	1907-1940	Community septic tank. Effluent discharged to drainage ditch.
	1940-1949	Septic tank effluent discharged to river.
	1949-	Primary treatment. Effluent discharged to river in winter and to land in summer.
West Sacramento	1930-1954	Raw sewage discharged to river.
	1954-	Primary treatment. Effluent discharged to river.
Sacramento	1850-1954	Raw sewage collected in sumps and pumped to river.
	1954-	Primary treatment. Effluent discharged to river.
Sacramento(Meadow-view plant serving south area)	1958-	Primary treatment. Effluent discharged to river.
American Crystal Sugar Company	1935-1959	Domestic wastes discharged to river after one day ponding with industrial wastes.
	1959-	Secondary treatment of domestic sewage. Effluent to river after ponding.
Hood	1900-1940	Individual septic tanks. Effluent to drains occasionally reaching river.
	1940-	Individual underground disposal systems. No discharges.
Walnut Grove	1930-	Septic tank systems. Several systems discharge effluent to river. A town hotel discharges raw sewage directly to river.
Isleton	1906-1956	Sewage and cannery wastes discharged via ditches to Georgianna Slough.
	1956-	Primary sewage treatment. Effluent to river.
Rio Vista	1912-1914	Two raw sewage discharges to river.
	1954-	Primary treatment. Effluent discharged to river.

the following decade. The history of sewage discharges to the Sacramento River is summarized in Table 3.11.

Present Discharges to Sacramento River

Quantities of sewage treatment plant effluents discharged directly to the river in 1960 are listed in Table 3.12 and locations of the discharges are shown on Plate 1. Discharges from other sewage treatment plants in the Sacramento area reach the river indirectly by means of drains and tributaries. The sanitary aspects of the wastes are discussed below and the mineral characteristics are presented in Appendix B.

Table 3.12

SEWAGE TREATMENT PLANT DISCHARGES TO SACRAMENTO RIVER

1960

Communities	Treatment Facilities: Date of Construction	Treatment Facilities: Type of Treatment	Design Flow (MGD)	Average Flow (MGD)
Redding	1948	Primary	3.75	2.1
Red Bluff	1952	Primary	0.9	1.1
Corning	1949	Primary*	0.4	0.2
West Sacramento	1954	Primary	5.0	2.0
Sacramento (main plant)	1954	Primary	54	49.4
Sacramento (Meadowview plant)	1958	Primary	2.75	0.2
Isleton	1956	Primary	0.65	0.1
Rio Vista	1954	Primary	0.72	0.2

* Land disposal in summer.

Table 3.13

SANITARY ANALYSES OF SEWAGE TREATMENT PLANT EFFLUENTS
1960-61

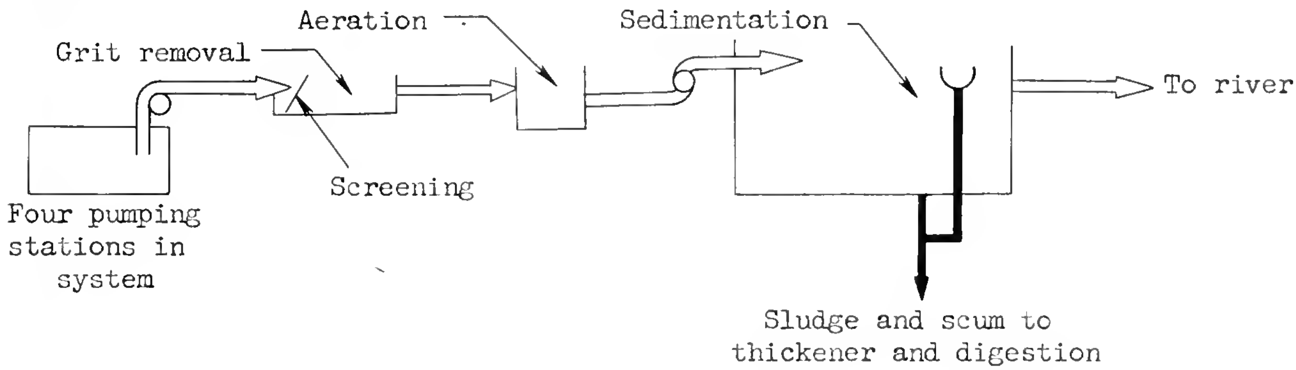
	Redding Effluent					Red Bluff Effluent					West Sacramento Effluent					Sacramento Effluent				
	BOD mg/L	Sus. Solids mg/L	Sett. Solids ml/L	Ether Sol. mg/L	ABS mg/L	BOD mg/L	Sus. Solids mg/L	Sett. Solids ml/L	Ether Sol. mg/L	ABS mg/L	BOD mg/L	Sus. Solids mg/L	Sett. Solids ml/L	Ether Sol. mg/L	ABS mg/L	BOD mg/L	Sus. Solids mg/L	Sett. Solids ml/L	Ether Sol. mg/L	ABS mg/L
1960																				
April	167	93			4.2	141	99			8.8	128	50			8.8					
May	168	37			5.2	150	56			5.4	117	94			9	174	55			4.2
June																				
July	96					76	43				85					92				
Aug.	100					150					70					104				
Sept.	98					83					95	48		69	7.5	99	40		6.6	3.3
Oct.	106	100		38	6.6	142	100		37	6.3	152	86		46	7.9	146	74		40	3.6
Nov.	150		3	44	5.6	102		1.4	49	6.5	145		0.8	63	11	164		0.1	46	6.7
Dec.	138	80	1.2	31	4.4	109	64	0.4	34	3.8	176	70	1.1	60	7.1	168	76	1.3	58	8.0
Jan.	164	84	0.7	36	7.3	166	102	1.5	50	6.8	194	104	0.1	40	10.6	186	142	0.2	70	7.0
Feb.	63	44	1.0	18	1.9	140	84	1.0	38	4.3	166	92	0.1	52	8.1	193	90	0.3	53	5.4
March	124	56	0.7	36	4.1	134	88	0.8	43	7.5	197	80	0.2	43	11	176	88	0.2	44	5.1
April	323	84	0.2	36		179	104	0.7	46		202	68	0.1	47		192	74	0.2	31	
May	127	58	0.4	35		169	88	0.7	27		211	80	0.2	52		186	82	0.1	40	
June	175	116	0.6	47		148	124	1.3	52		163	120	0.1	48		146	76	0.1	38	

Monthly composite samples of sewage effluent were collected at the Redding, Red Bluff, West Sacramento, and Sacramento sewage streatment plants during the Sacramento River survey. A complete presentation of all analyses performed on the monthly samples is included in the basic data sheets. The results of the sanitary analyses are summarized in Table 3.13. In addition, samples were collected at sewage treatment plant discharged during intensive four-day sampling periods; results of these analyses are discussed in Appendixes B and C.

Detailed information regarding the eight community sewage discharges to the Sacramento River, the treatment works and the discharge requirements adopted by the Central Valley Regional Water Pollution Control Board (No. 5) is presented in the following pages.

Redding Sewage Treatment Plant

Location of Discharge: Sacramento River at mile 293.8, right bank.
Type of Treatment: Primary
Flow Diagram:



Estimated Connected Population: 12,500
Present Flow (monthly average in MGD):

1960						1961	
Jan.	3.2	May	1.6	Sept.	1.5	Jan.	1.8
Feb.	2.5	June	1.9	Oct.	1.2	Feb.	3.4
Mar.	2.4	July	1.9	Nov.	1.4	Mar.	2.6
April	1.5	Aug.	1.7	Dec.	2.8	April	2.0

Design Flow: 3.75 MGD. Designed for 25,000 population at 100 gcd and 50 gcd infiltration.

Type of Wastes: Domestic Sewage from Redding and Enterprise. Small amount of waste water from two dairies.
Chlorination Practice: None
Remarks: Solids removed in the grit chamber are pumped to the river. There is a large amount of infiltration in the collection system during the winter months.

Sanitary Analyses:

	Influent	Effluent
5-Day BOD (ppm)	155	146
Settleable Solids (ml/L)	5.4	1.5
Suspended Solids (ppm)	127	70
Ether Solubles (ppm)	54	39

Results are an average of three 10-hour composite samples collected in November 1960, January 1961, and March 1961.

Coliform Bacteria in Effluent (geometric mean), MPN/100 ml: June 1960 - 38,200,000: October 1960 - 39,000,000

Water Pollution Control Board Requirements
Resolution No. 57-5, January 10, 1957:

1. Discharge shall be adequately disinfected or its equivalent,
2. Discharge shall not contain more than 0.5 ml/liter of settleable solids,
3. Discharge shall not contain more than 15 ppm of ether soluble materials,
4. Discharge shall not provide visible grease or recognizable sewage solids in the river,
5. Discharge shall be sufficiently well oxidized to prevent unsightliness due to fungus growths in the Sacramento River,
6. Neither the treatment plant nor its discharge shall cause a nuisance by reason of odors or unsightliness.

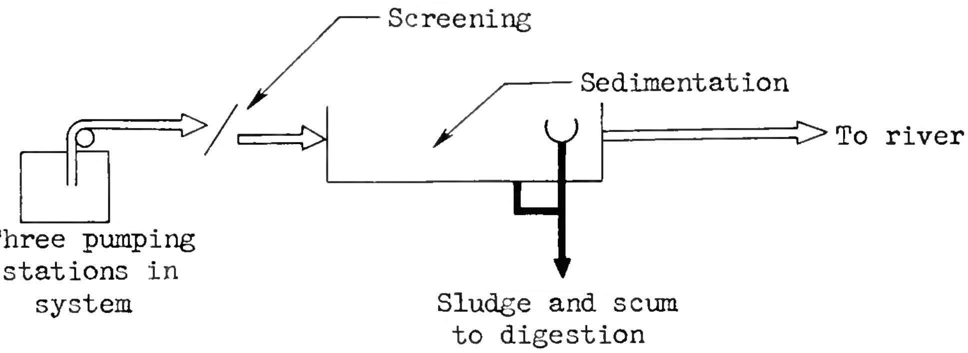
The normal waste flow from the City of Redding is nearly all domestic sewage; the only industrial waste is from two small dairies. During storm periods in the winter, instantaneous peak flows of 8 MGD have arrived at the plant. In the dry season there is little fluctuation in the daily amount of sewage. Except during storm periods, the sewage flows are within the design flow of the plant.

In May 1961, a report by the Bureau of Sanitary Engineering, State Department of Public Health, recommended that the City of Redding provide two-stage chlorination to prevent contamination of the river by

discharge. Detailed recommendations regarding disinfection were sent to the Central Valley Regional Water Pollution Control Board.

Red Bluff Sewage Treatment Plant

Location of Discharge: Sacramento River at mile 242.8, right bank.
Type of Treatment: Primary.
Flow Diagram:



Estimated Connected Population: 6,50C
Present Flow (monthly average in MGD):

		1960				1961	
Jan.	No Record	May	0.9	Sept.	1.1	Jan.	1.0
Feb.	No Record	June	1.2	Oct.	1.0	Feb.	1.2
March	1.0	July	1.2	Nov.	1.0	March	1.0
April	0.9	Aug.	1.2	Dec.	1.1	April	1.0

Design Flow: 0.9 MGD.
Type of Wastes: Domestic sewage from Red Bluff and significant amount of industrial waste from a slaughter house and tallow works. Minor flow from a plywood plant.
Chlorination Practice: None.
Remarks: Industrial flow from the slaughter house and rendering plant is discharged to the sewerage system during the night-time low-flow period.

Sanitary Analyses:

	Influent	Effluent
5-Day BOD (mg/L)	168	125
Settleable Solids (mg/L	3.7	1.1
Suspended Solids (mg/L)	140	86
Ether Solubles (mg/L)	66	43

Results are averages of three 10-hour composite samples collected in November 1960, January 1961, and March 1961.

Coliform Bacteria in Effluent (geometric mean), MPN/100 ml: June 1960 - 30,400,000; October 1960 - 29,000,000.

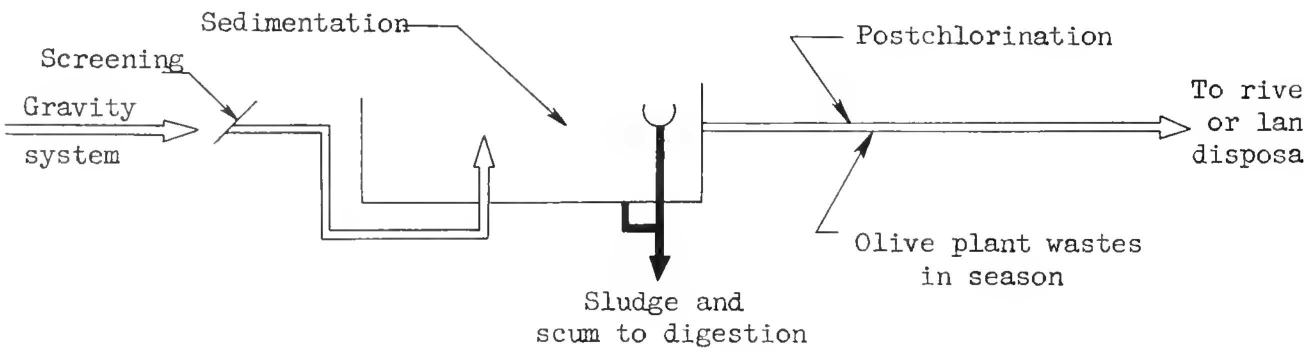
Water Pollution Control Board Requirements.
Resolution No. 34 (51-13), March 22, 1951.

1. No recognizable sewage solids in the river.
2. No visible grease of sewage origin in the river.
3. No floating material of sewage origin in the river.
4. Neither the plant nor the effluent shall cause a nuisance or pollution.
5. Neither the plant nor the effluent shall cause a contamination.

Daytime flows are primarily domestic sewage with a minor amount of process water from a plywood manufacturing plant. During night-time hours when domestic flows are low, waste water from a slaughterhouse and meat by-products plant are discharged into the sewerage system. The two meat plants first started discharging into the sewerage system in the summer of 1960. The sewage treatment plant is presently operating at flows in excess of design.

Corning Sewage Treatment Plant

Location of Discharge: Sacramento River at mile 217.6, right bank.
Type of Treatment: Primary.
Flow Diagram:



Estimated Connected Population: 3,000
Present Flow: Flows are not metered. Estimated 0.25 MGD.
Design Flow: 0.4 MGD.
Type of Wastes: Domestic sewage from Corning. Industrial waste water from five olive processing plants is by-passed to the river.
Chlorination Practice: When sewage is discharged to river, 10 ppm chlorine is applied to effluent.
Remarks: Treatment plant effluent discharged to the river from October to May; during the summer months, it is used to irrigate grazing land.

Water Pollution Control Board Requirements.
Resolution No. 53-34, August 29, 1953.

1. Domestic sewage discharged to the Sacramento River shall be effectively disinfected.
2. Discharge shall not reduce the dissolved oxygen content of the Sacramento River below 80 percent of saturation.
3. Discharge shall not produce visible solids recognizable as of sewage or waste origin in the Sacramento River.
4. Discharge shall not produce visible grease recognizable as sewage or waste origin in the Sacramento River.
5. Discharge shall not produce deleterious materials in Sacramento River in concentrations injurious to animal, plant, or aquatic life.
6. Neither the plant nor its effluent shall cause a nuisance or a pollution.

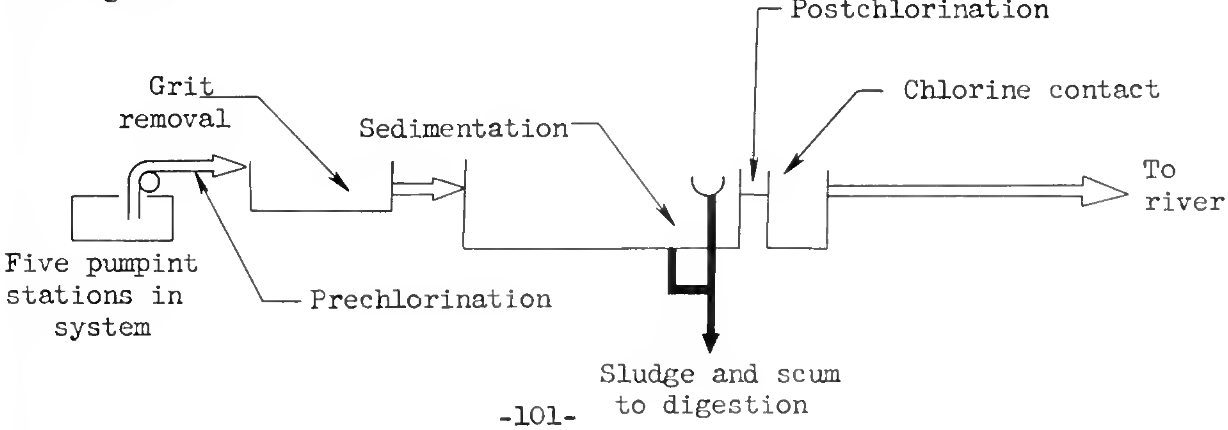
The plant treats domestic sewage from the community of Corning. The discharge to the Sacramento River is combined sewage effluent and seasonal wastes from seven olive processing plants. The olive plant discharges, mostly wash water and brine, are screened at the olive plants and by-pass the sewage treatment plant; the quantity and quality of these discharges were not determined.

In the summer months the domestic sewage effluent is used for irrigation; at other times it is discharged to the Sacramento River after chlorination.

Insufficient samples were collected at the plant to permit an evaluation of influent and effluent characteristics.

West Sacramento Sewage Treatment Plant

Location of Discharge: Sacramento River at mile 58.0, right bank.
Type of Treatment: Primary:
Flow Diagram:



Estimated Connected Population: 20,000
Present Flow (monthly average in MGD):

		1960					1961		
Jan.	1.57	May	1.62	Sept.	1.91	Jan.	1.61	May	1.6
Feb.	1.64	June	1.96	Oct.	1.72	Feb.	1.49	June	1.9
March	1.63	July	2.00	Nov.	1.63	March	1.60		
April	1.62	Aug.	1.87	Dec.	1.58	April	1.60		

Design Flow: 5.0 MGD
Type of Wastes: Domestic sewage from West Sacramento, Bryte and Broderick. Industrial waste flow from slaughterhouses.
Chlorination Practice: Continous prechlorination for odor control at about 18 ppm. Postchlorination during recreational season (air temperature $80^{\circ}F$) at 10 ppm. Chlorine residual, 0.5 ppm after 1 hour contact time.
Remarks: All sewage arriving at the plant is pumped through five pumping stations resulting in rapid, extreme fluctuations in flow.

Sanitary Analyses:

	Influent	Effluent
5-Day BOD (mg/L)	197	179
Settleable Solids (ml/L)	3.7	0.4
Suspended Solids (mg/L)	162	91
Ether Solubles (mg/L)	79	49

Results are an average of three 10- hour composite samples collected in November 1960, January 1961, and March 1961.

Coliform Bacteria in Effluent (geometric mean) MPN/100 ml: June 1960 - 460; August 1960 - 2,110; October 1960 - 300.

Water Pollution Control Board Requirements,
Resolution No. 23 (51-2), January 25, 1951.

1. Maximum discharge of 5-day $20^{\circ}C$ BOD in any one day - 6,000 pounds.
2. Miximum quantity of settleable solids - 0.5 ml/L.
3. Maximum quantity of ether soluble material - 15 ppm.
4. There will be no floating material of sewage origin discharged to the river.
5. There will be no gross sewage solids discharged to the river.
6. The effluent must be adequately disinfected.
7. Neither the plant nor the discharge shall create a nuisance or pollution.
8. The discharge shall not cause a contamination in the Sacramento River.

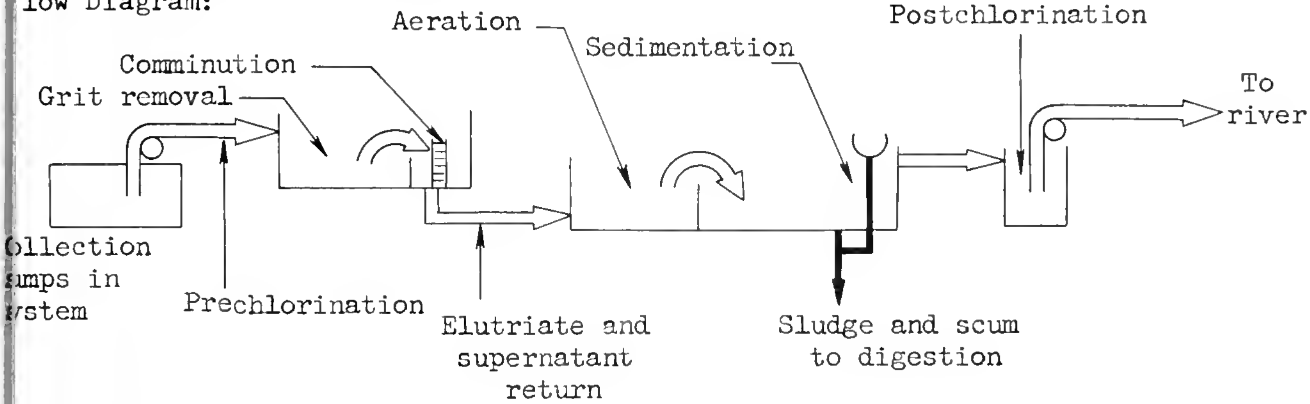
The waste water arriving at the West Sacramento sewage treatment plant is principally domestic sewage and slaughterhouse wastes. There is no gravity flow to the sewage treatment plant and the independent operation of five pumping stations in the system has on occasion changed

he flow arriving at the sewage treatment plant from o to 4.5 MGD within few minutes.

Coliform bacteria densities in the effluent indicate the effectiveness of chlorination practice at the plant. In addition to pre- and postchlorination at the sewage treatment plant the sewage is chlorinated t the pumping stations for odor control.

Sacramento Sewage Treatment Plant

ocation of Discharge: Sacramento River at mile 54.09, left bank.
ype of Treatment: Primary.
low Diagram:



stimated Connected Population: 282,00
resent Flow (monthly average in MGD):

1960						1961			
an.	41.2	May	47.0	Sept.	65.3	Jan.	41.8	May	48.4
eb.	41.4	June	53.7	Oct.	54.5	Feb.	44.1	June	55.8
arch	43.8	July	52.0	Nov.	45.9	March	45.5		
pril	46.3	Aug.	60.2	Dec.	41.0	April	49.8		

esign Flow: 33 MGD; Average Daily Domestic
54 MGD; Average Daily (Canning Season)
76 MGD; Maximum Hourly
ype of Wastes: Domestic sewage from Sacramento, North Sacramento and four sanitation districts. Industrial wastes from five major canneries andasynthetic detergent plant.
hlorination Practice: Continuous prechlorination of 10 ppm for odor control. Postchlorination during recreational season (air temperature 80°F) from 1 - 4 ppm, depending on downstream water quality.
emarks: Peak flows occur during the fall canning season.

anitary analyses of plant influent and effluent are summarized in Table 3.14.

A representative sampling point for the bacteriological quality f the effluent was not available. In June, samples collected from the

Table 3.14

SANITARY ANALYSES, SACRAMENTO SEWAGE TREATMENT PLANT, 1960*

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
5-Day BOD (ppm)													
Influent	173	172	185	175	167	147	158	248	276	248	222	212	199
Effluent	136	130	141	126	118	94	100	166	199	159	162	162	141
Percent Removal	21	24	24	28	29	36	37	33	28	36	27	24	29
BOD to River (1,000 lb./day)	46.7	44.9	51.5	48.6	46.2	42.1	43.4	83.3	108.4	72.3	62.0	55.4	58.7
Settleable Solids (ml/L)													
Influent	3.9	4.9	4.3	4.1	4.1	3.9	3.5	5.7	9.6	6.4	3.7	4.8	4.9
Effluent	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2
Suspended Solids (ppm)													
Influent	164	161	165	160	163	140	137	153	139	143	146	155	152
Effluent	101	88	81	92	85	73	65	75	65	59	73	92	79
Percent Removal	62	55	52	58	52	52	47	49	47	40	50	59	52
Ether Solubles (ppm)													
Influent	67	52	72	85	76	64	51	58	45	56	---	52	62
Effluent	33	30	39	32	34	28	22	22	22	22	---	31	29
Percent Removal	51	42	46	62	55	56	57	62	50	61	---	41	53

effluent sump at the plant immediately after postchlorination. Because of the short chlorine contact period, bacteriological results were high. In the August-September and October periods samples were collected from the stream of sewage at the river outfall 20 - 30 minutes from the plant. Although there may have been some dilution with river water, these results are considered more representative of the bacteriological quality of the effluent entering the river.

Period	Coliform MPN/100 ml (geometric mean density)
June 20-24, 1960	402,200
August 29-September 2, 1960	43,500
October 24-28,1960	124 ,000

Water Pollution Control Board Requirements,
Resolution No. 7 (50-7), July 13, 1950.

1. Maximum discharge of 5-day 20 C°BOD in any one day 130,000 lbs.
2. Maximum quantity of settleable solids - 0.5 ml/liter.
3. Maximum quantity of ether soluble material - 15 ppm.
4. There will be no floating material discharged to the river.
5. There will be no gross sewage solids discharged to the river.
6. The effluent must be adequately disinfected.
7. Neither the treatment plant nor the discharge shall create a nuisance.
8. The discharge from the treatment plant shall not cause a contamination in the Sacramento River.

The Sacramento sewage treatment plant provides primary treatment for the domestic and industrial waste water from the City of Sacramento, the City of North Sacramento, Hagginwood Sanitary District, Sacramento County Sanitation Districts No. 1 and No. 2, and Arden Watt Sewer Maintenance District.

During dry weather all sewage with the exception of that from County Sanitation District No. 1 is collected at one of two sumps in the city and is pumped to the treatment plant. District No. 1 discharges directly to the sewage treatment plant. The pumping schedule at the main city sump is arranged so that the amount of sewage arriving at the treatment plant is fairly constant over a 24-hour period. In wet weather, the quantity of storm flow in excess of the design capacity of the sewage treatment plant is pumped directly to a river from the two sumps.

The major industrial waste flow is from five large canneries. These canneries are required by city ordinance to pass the waste water through 20 mesh screens before discharging to the sewerage system. March through May is a minor cannery period when asparagus and spinach is processed and consequently there is a rise in the 5-day BOD during this period.

There is a seasonal increase in the amount of waste water arriving at the treatment plant in the summer months due to the addition of water used for air conditioning. This waste water dilutes the sewage causing a reduction in the 5-day BOD during June and early July, before the major cannery season has begun. It has been estimated that as much as 10 MGD of water used for cooling government buildings in the city is presently discharged to the system. The major cannery season begins in the latter part of July when tomatoes, peaches and apricots are harvested with consequent increases in waste water flow and 5-day BOD which reach a peak in September.

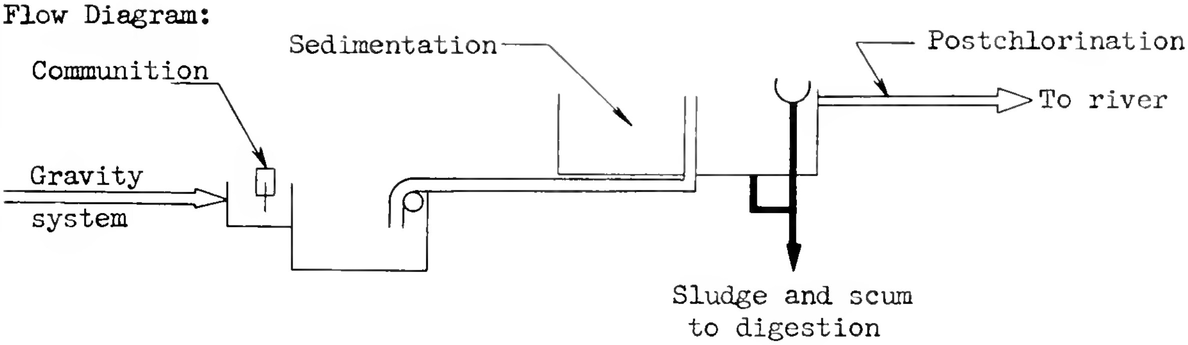
Laboratory analyses of plant influent and effluent indicate a 5-day BOD reduction in the range expected for a primary sewage treatment plant.

Foam has been observed on several occasions extending several hundred yards below the outfall. Although a detergent plant discharges wastes to the sewerage system, no relationship between the periodic occurrences of foaming and the detergent processing operation has been reported.

Meadowview Sewage Treatment Plant

Location of Discharge: Sacramento River at mile 47.7, left bank.
Type of Treatment: Primary.

Flow Diagram:



Present Flow: Estimated 0.2 to 0.3 MGD
Estimated Connected Population: 2,100
Design Flow: 2.75 MGD
Type of Wastes: Domestic sewage from the south Sacramento residential area.
Chlorination Practice: Chlorination facilities are in place but have not been operated because of the low flows.
Sanitary Analyses:
Effluent 5-Day BOD (20°C): Maximum - 236 mg/L; Minimum - 88 mg/L; Average - 160 mg/L; (20 grab samples).
Coliform Bacteria in Effluent (geometric mean) MPN/100 ml: August 1960 - 22,100,000; October 1960 - 30,500,000.

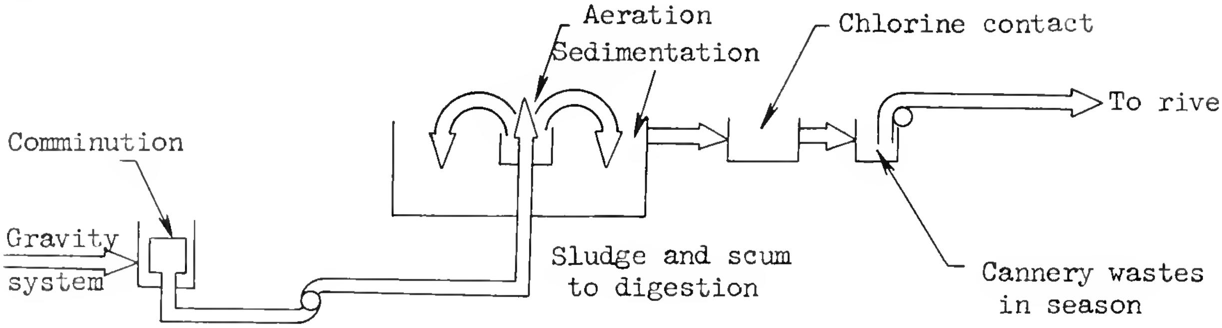
Water Pollution Control Board Requirements,
Resolution No. 57-4, January 10, 1957.

1. Discharge shall be adequately disinfected or its equivalent.
2. Discharge shall not contain more than 0.5 ml/liter of settleable solids.
3. Discharge shall not contain more than 15 ppm of ether soluble material
4. Discharge shall not contain gross floating solids.
5. Discharge shall not cause detectable taste or odor in the receiving water.
6. Discharge shall not contain toxic substances in concentrations deleterious to human, animal, plant, or aquatic life.
7. Discharge shall not depress the dissolved oxygen content of the Sacramento River below 5.0.
8. Discharge shall be sufficiently well oxidized so as to prevent unsightliness due to fungus growths in the Sacramento River.
9. Neither the treatment plant nor its discharge shall cause a nuisance by reason of odors or unsightliness.

The Meadowview sewage treatment plant was constructed in 1958 to serve the rapidly developing residential area south of the main part of Sacramento. The plant is presently loaded to less than 20 percent of capacity. Plant operation and maintenance is performed by personnel from the main Sacramento sewage treatment plant. Present flows are too low to permit accurate measurement.

Isleton Sewage Treatment Plant

Location of Discharge: Sacramento River at mile 18.1, left bank.
Type of Treatment: Primary
Flow Diagram:



Estimated Connected Population: 1,600
Present Flow (monthly average in MGD):

		1960						1961	
Jan.	0.13	May	0.13	Sept.	0.13	Jan.	0.15	May	0.13
Feb.	0.13	June	0.13	Oct.	0.12	Feb.	0.15	June	0.13
March	0.13	July	0.13	Nov.	0.12	March	0.13		
April	0.13	Aug.	0.13	Dec.	0.15	April	0.13		

Design Flow: 0.65 MGD
Type of Wastes: Domestic sewage from Isleton. Occasional small quantities of water from a pickle plant. Screened wash water from a cannery is mixed with effluent at the effluent wet well. It does not pass through the plant.
Chlorination Practice: Postchlorination during recreational season (when air temperature 80°F) dosage is 10 - 25 lb./day and residual of 0.5 - 2.0 ppm after two hours contact period is maintained.
Remarks: The normal domestic sewage flow is 0.13 - 0.15 MGD. There is a minor flow (8 MG/year) of water from a pickle plant. From March to June there is a flow of 0.5 - 0.8 MGD from a cannery which enters the plant at the effluent sump and is pumped into the Sacramento River with the plant effluent; sanitary analyses of this waste were not performed.

Sanitary Analyses:
Effluent 5-Day BOD (20°C): Maximum - 108 mg/L; Minimum - 36 mg/L; Average - 76 mg/L; (30 grab samples)
Coliform Bacteria in Effluent (geometric mean) MPN/100 ml: June 1960 - 356,000 (chlorinator out of operation during two days of sampling period); August 1960 - 620; October 1960 - 34,800.

Water Pollution Control Board Requirements,
Resolution No. 113 (52-5). February 20, 1952.

1. The domestic sewage effluent shall receive adequate disinfection or its equivalent effect before discharge to the Sacramento River;

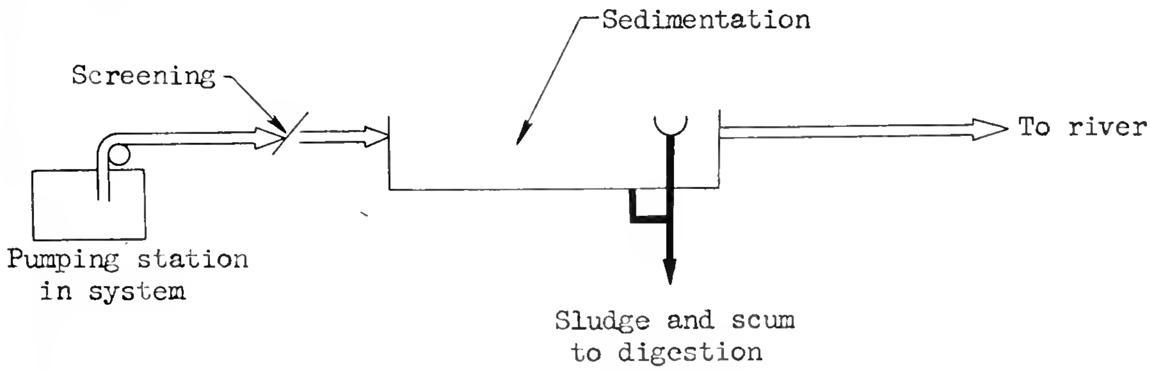
2. The discharge shall not cause the formation of sludge deposits in the river or the accumulation of objectionable deposits on or along the banks of the river;
3. The discharge shall not contain solids of recognizable sewage origin or produce signs of visible grease in the river except that, unavoidable discoloration in the immediate vicinity of the outfall will be permitted;
4. The discharge shall not cause the dissolved oxygen content of the river water to be depressed below 5.0 ppm;
5. Neither the discharge nor the disposal shall cause a nuisance or create a pollution of the Sacramento River or the disposal area.

The sewage treatment plant treats the domestic sewage from the small community of Isleton. Process water from a cannery in town is screened at the cannery and is discharged to the treatment plant effluent well. A minor flow of wash water from a pickle plant passes through the treatment plant.

The plant is normally operating well within its design capacity. During winter storms, high flows arrive at the plant for short periods.

Rio Vista Sewage Treatment Plant

Location of Discharge: Sacramento River at mile 11.6, right bank.
Type of Treatment: Primary.
Flow Diagram:



Connected Population: 1,800
Present Flow (monthly average in MGD):

1960						1961			
Jan.	0.15	May	0.19	Sept.	0.27	Jan.	0.13	May	0.19
Feb.	0.13	June	0.33	Oct.	0 21	Feb.	0.15	June	0.28
March	0.14	July	0.34	Nov.	0.20	March	0.17		
April	0.18	Aug.	0.32	Dec.	0.17	April	0.17		

Design Flow: 0.72 MGD
Type of Wastes: Domestic sewage from Rio Vista.
Chlorination Practice: None.

Sanitary Analyses:
Effluent 5-Day BOD (20°C): Maximum - 175; Minimum - 27; Average - 86; (30 grab samples).
Coliform Bacteria in Effluent (mean density) MPN/100 ml: June 1960 - 11,600,000; August 1960 - 14,000,000; October 1960 - 13,200,000

Water Pollution Control Board Requirements, Resolution No. 1 (50-1), April 7, 1950.

1. Maximum discharge - 400,000 gallons per day.
2. Maximum 5-Day 20°C BOD of effluent - 260 ppm.
3. Maximum quantity of suspended solids - 120 ppm.
4. There will be no gross solids in the effluent.
5. Maximum quantity of ether soluble material - 2 ppm.
6. It is also necessary that the discharge shall conform to any bacterial standards which may be set by the State Department of Public Health.

Discussion:

The plant treats the domestic sewage of Rio Vista, There is no significant industrial flow. Sewage is pumped to the treatment plant from a pumping station in the collection system, and because of the large size of the sump, during low flow periods the sewage arriving at the plant is septic.

The State Department of Public Health has recommended that the city install effluent disinfection facilities at the plant and provide 0.5 ppm chlorine residual after 30 minutes contact.

Present Discharges to Tributary Streams

Although there are a number of sewage treatment plants which discharge to various tributary streams, the locations and flows of only those plants serving communities and industries north and east of Sacramento are of significance to the Sacramento River. Locations of these plants and information regarding them are given in Figure 3.5 and Table 3.15, respectively. It can be seen from the figure that the discharge eventually reach the Sacramento River by either the Natomas East Main Drain

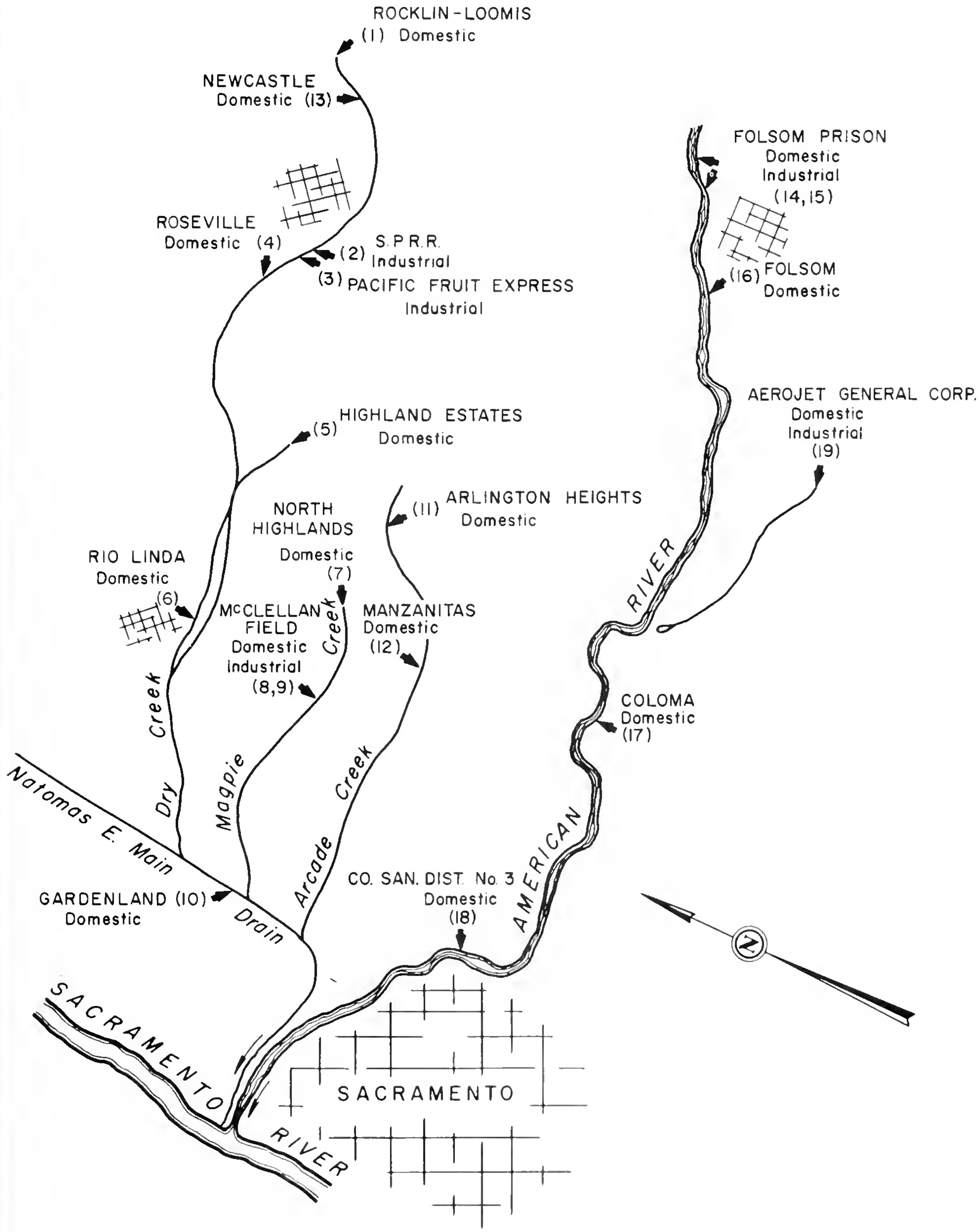


Figure 3.5. WASTE DISCHARGES IN THE GREATER SACRAMENTO AREA

Table 3.15

WASTE DISCHARGES IN GREATER SACRAMENTO AREA ENTERING SACRAMENTO RIVER VIA TRIBUTARIES AND DRAINS

Map No. (Figure 3.5)	Name	Type of Waste and Estimated Connected Population	Average Flow (MGD)	Type of Treatment	Disinfection Practices	Receiving Waters	Remarks
1.	Rocklin-Loomis Municipal Utility District	Domestic sewage. 1,750 population	Est. 0.25	Septic tank and 30-day ponds.	None	Antelope Creek to Dry Creek	
2.	Southern Pacific R.R. (Roseville)	R.R. car wash water	---	Pond	---	Dry Creek	
3.	Pacific Fruit Express (Roseville)	Truck wash water and cooling water.	---	---	---	Dry Creek	
4.	Roseville	Domestic sewage. 12,000 population.	Summer 1.5 Winter 1.7	Secondary - single stage trickling filter.	Year-round postchlorination at a constant rate with average residual after 25 minutes contact is 0.7 ppm.	Dry Creek	Plant expansion began June 1961.
5.	Highland Estates Sewer Assessment District	Domestic sewage. 500 population	0.05	Secondary - single stage trickling filter.	Continuous postchlorination.	Dry Creek	
6.	Rio Linda County Water District	Domestic sewage. 1,800 population	0.3	Primary and 30-day ponds.	Continuous constant rate postchlorination and 30-day ponds.	Dry Creek	
7.	North Highlands County Sanitation District No. 6	Domestic sewage and laundry wastes	1.4	Secondary - two stage trickling filter.	Continuous postchlorination.	Magpie Creek	
8.	McClellan Field AFB Domestic	Domestic sewage	Summer 1.3 Winter 0.8	Secondary - two stage trickling filter.	Continuous postchlorination. 2.0 ppm residual after 5-1/2 contact period.	Magpie Creek	
9.	McClellan Field AFB Industrial	Metal plating wastes, solvent still, paint filter, airplane and vehicle shop wastes and wash water.	0.37	Oil flotation, gravity separation. Phenolic wastes discharged to sewage treatment plant (5,000 gpd).	None required.	Magpie Creek	
10.	Gardenland County Sanitation District No. 7	Domestic sewage.	0.32	Primary and 45-day detention ponds	Prechlorination for odor control.	Natomas East Main Drain	
11.	Arlington Heights Sewer Maintenance District	Domestic sewage		Secondary - single stage trickling filter followed by sand filter.	Continuous postchlorination.	Cripple Creek to Arcade Creek	
12.	Manzanitas Sewer Assessment	Domestic sewage.	0.25	Secondary - two stage trickling filters.	Continuous postchlorination.	Arcade Creek	
13.	Newcastle Sanitary District	Domestic sewage	0.025	Primary (Imhoff tank)	None	Dry Creek	Plant improvements planned.
14.	Folsom-Prison (Industrial)	Cannery, license plate factory, dairy and furniture factory wastes.	Est. 1.0	Holding and evaporation.	None required.	American River	
15	Folsom Prison (Domestic)	Domestic sewage.	0.75	Secondary - activated sludge.	Continuous postchlorination. Residual of 2.0 ppm cl^- after 25 min. contact.	American River	
16.	Folsom	Domestic sewage.	0.4	Secondary - single stage trickling filter and ponds.		Possible seepage to American River	
17.	Coloma Sewer Maintenance District	Domestic sewage	0.8	Secondary - activated sludge and 3-day ponds.	Continuous postchlorination. Chlorine residual of 0.4 ppm after 30 min. contact.	American River	
18.	County Sanitation District No. 3	Domestic sewage	2.0	Secondary - two stage trickling filters.	Continuous postchlorination. Chlorine residual of 0.6 ppm after 45 min. contact.	American River	

or the American River. Both enter the east side of the Sacramento River at river mile 60.4 within a few hundred yards of each other, immediately upstream from the City of Sacramento water intake.

Future Discharges

Disinfection facilities are presently being installed at the Redding sewage treatment plant. The plant has sufficient capacity to treat the expected increase in flows from the city for the near future. When present facilities become inadequate, it is proposed in the City of Redding's master plan that new facilities will be constructed south of town.

The sewage treatment plant at Red Bluff is overloaded by 15 to 20 percent during a significant portion of the year. The city is presently investigating the possibility of obtaining another site for sewage treatment facilities and may revert to land disposal of the effluent from the new sewage treatment plant. It is, therefore, possible that there will be no sewage discharged to the Sacramento River from Red Bluff after new sewage treatment facilities have been constructed.

The Sacramento area is undergoing a rapid population expansion and a number of changes and additions to the present sewage treatment facilities are proposed. A new secondary sewage treatment plant has been proposed to serve the area north of Sacramento on the east side of the Sacramento River known as the Natomas Sewer Maintenance District. The plant will have a design capacity of 4.5 MGD. The initial stage will provide primary treatment and ponds. Eventually, as the sewage flows increase, the effluent from the treatment plant will be discharged to the East Drainage Canal of the Natomas Main Drain and will reach the Sacramento River at river mile 61.5 which is approximately two miles above Sacramento.

A new sewage treatment plant under county supervision and operation is under construction to serve the area northeast of Sacramento along the American River. The initial design capacity of the secondary treatment plant will be 9 MGD. The effluent from the plant will enter the American River approximately 12 miles above its confluence with the Sacramento River.

The Southeast Sanitation District plant is presently under construction southeast of the City of Sacramento which will treat the sewage from new subdivisions in county areas. The plant will provide intermediate treatment with an initial design capacity of 8 MGD and an ultimate capacity of 48 MGD. The effluent will enter the Sacramento River at mile 46 which is approximately 14 miles below Sacramento.

No plans have been made as yet by the City of Sacramento for expansion or modifications of the Sacramento main plant. The Meadowview sewage treatment plant is presently operating far below its design capacity.

The sewage treatment plant for West Sacramento has undergone additions and modifications which will enable it to handle sewage from the West Sacramento area without further expansion for a number of years.

The present sewage treatment plants at Isleton, and Rio Vista have sufficient capacity to treat any expected increase in wastes from the communities in the forseeable future. Installation of disinfection facilities at the City of Rio Vista sewage treatment plant has been recommended by the State Department of Public Health. Waste discharge requirements are being established for the sewage discharge from the hotel at Walnut Grove. It is anticipated that treatment facilities will be required if this discharge is to continue.

The other small communities in southern area such as Courtland, Clarksburg, and Locke are not expected to increase in population to such a degree that sewage treatment facilities or a discharge to the Sacramento River will be necessary in the near future.

Industrial Wastes

The two significant industrial waste discharges to the Sacramento River are from a wood products plant near Red Bluff and a sugar beet processing plant at Clarksburg. Minor discharges include several log pond overflows in the Redding - Red Bluff area (the only sizeable overflow, 1 MGD, reaches the Sacramento River via Anderson Creek), an intermittent discharge of diluted battery acid near Sacramento, cooling water from a food storage plant at Hood, and wastes from a mushroom plant near Locke. Seasonal occurrences of tastes and odors in the Sacramento water supply are believed to be associated with an industrial discharge from a military installation which eventually reaches the Sacramento River a short distance upstream from the water intake.

Slaughterhouses, dairies, canneries, olive processing plants and numerous small industries are served by other sewerage systems that discharge to the Sacramento River. These have been discussed in preceding paragraphs.

Diamond National Corporation

The Diamond National Corporation plant located two miles south of Red Bluff produces molded paper products such as plates and trays. About 0.5 MGD of waste is produced which contains sulfur compounds, silica, and wood pulp. About 1.5 MGD of waste consists of supernatant containing wood fiber from molded pulp processing operations. Wastes from both processes are settled with alum and treated with lime to control the pH.

The effluent is discharged to a settling pond and overflows to a leaching pond located beside Redbank Creek. The creek flows into the Sacramento River one mile below the ponds. The pond contents are normally a dark color with a strong sulfur odor. During one inspection, a flow of approximat 70 gallons per minute was flowing into Redbank Creek through a drain line at the effluent end of the pond. On all other inspections there was no direct discharge from the ponds although an estimated flow of 0.4 mgd seeps through the banks of the ponds into the creek. The ponds are emptied annually for cleaning.

The major discharge into Redbank Creek is a continuous flow of 1.5 mgd from the 26-acre log pond.

Domestic sewage at the plant is discharged to a septic tank and leaching field. During the summer months there is no flow in Redbank Creek other than the waste discharges from the Diamond National Corporation.

Water Pollution Control Board Requirements. Resolution No. 60-12, February 18, 1960:

1. The volume of surface flow discharges from all sources shall not exceed the rate calculated by the formula:

$$\text{Maximum hourly flow in cfs} = 10 \times \frac{\text{Sacramento River flow in cfs}}{2500}$$

2. Waste discharges shall not contain more than 0.5 ml/liter of settle able solids.
3. The hourly average pH of discharges shall not fall below 6.5 nor exceed 8.5. At no time shall the pH of the average fall outside the range of 6.0 to 9.5
4. The discharge shall not cause the dissolved oxygen content of Sacramento River waters to fall below 7.0 ppm at any time.
5. Waste discharges shall not contain a monthly average concentration materials in excess of the following:

Sulfate	740 ppm
Chloride	20 ppm
Sodium	175 ppm
Magnesium	24 ppm
Fluorides	1 ppm
Silicon Dioxide	70 ppm
10-Minute Oxygen Demand	0 ppm
5-Day BOD	100 ppm

6. Waste discharges shall not cause objectionable color in the Sacramento River.

7. Waste discharges shall not cause detectable taste or odor in any public water supply.
8. Waste discharges shall produce no scum or floating materials of recognizable waste origin in the Sacramento River.
9. Waste discharges shall not contain any substances or materials of such character or quantity which, on mixing with water of the Sacramento River will produce conditions deleterious to human, animal, plant or aq uatic life.
10. Waste discharges shall not cause objectionable fungus growths in the Sacramento River channel, or along the banks thereof.
11. Waste discharges shall not cause the formation of sludge deposits.
12. Waste discharges shall not cause visible oil or grease slicks in the Sacramento River.
13. Waste discharges shall not cause the sodium ratio of Sacramento River water at the Corning Canal intake to exceed 35%.
14. Neither the waste discharges nor the disposal method shall cause a nuisance by reason of odors or unsightliness.
15. Waste discharges shall not cause a pollution of usable ground or surface waters.

Routine monitoring of waste discharges is carried out by the Diamond National Corporation. Samples for analysis are collected from the mouth of Redbank Creek, the Sacramento River above and below Redbank Creek, the Corning Canal intake further downstream on the river, and at nearby wells, Results of analyses of Redbank Creek water samples are given in Table 3.16. In addition to the constituents for which limits have been established in the waste discharge requirements, a number of analyses for other constituents are performed.

Table 3.16

WATER QUALITY AT MOUTH OF REDBANK CREEK*

Date	Settleable Solids (mg/L)	pH	Sulfate (mg/L)	Chloride (mg/L)	Sodium (mg/L)	Magnesium (mg/L)	Fluoride (mg/L)	5-Day BOD (mg/L)
4/60	0.1	7.7-8.4	77.8	7.3	22.9	20.5	0	2.0-17.3
5/60	0.1	6.8-8.6	213	7.7	89.0	12.0	0.1	3.0-90.0
6/60	0.1	7.6-8.1	185	16	56.0	21.5	0	2.0- 5.5
7/60	0.1	6.7	250	14	104	21.6	0	7.4-31
8/60	0.4	6.6	235	11	88.0	10.7	0	19 -34
9/60	0.1	7.0	250	8	92	16.8	0.1	19 -58
10/60	0.1	6.8	295	6	108	11.2	0.1	29 -49
11/60	0.1	7.1	300	18	108	14	0	32 -61
12/60	0.1	7.1	155	10	48.0	18.0	0	10 -15
1/61	0.1	6.8	188	16	76.0	7.4	0	19 -28
2/61	0.1	7.3	155	10	48	17.8	0	5 -12
3/61	0.1	7.6	95	16	36.1	14.6	0	6.8-12
4/61	0.5	6.8	100	18	35.6	14.4	0	4 -19

* Monthly averages of analyses by Diamond National Corporation.

American Crystal Sugar Company

The American Crystal Sugar Company processes sugar beets at a plant in Clarksburg, 15 miles south of Sacramento. The operating season is from early August to about December. After an initial two week break-in period, the plant operates at full capacity during the entire period. Plant operation began on August 9, and terminated December 1, 1960.

An average of 2,100 tons of sugar beets per day is processed to produce 550,000 pounds of sugar. The water use at the plant is as follows:

Use	Source	Average, MGD
Domestic	Wells	0.09
Cooling and process	Sacramento River	6.3

Most of the river water is first used for cooling. Approximately 35 to 40 percent of this is then returned directly to the river and the

rest of the cooling water is used in various phases of the sugar making process. The waste beet pulp slurry is dewatered to produce a stock feed by-product of the sugar process.

Sanitary sewage is discharged to the factory's sewage treatment plant where it passes through an Imhoff tank, trickling filter and final settling tank. The effluent is chlorinated and is discharged to the plant industrial waste sewer.

The combined cooling water, process water and sewage plant effluent is discharged into a 5-acre holding pond that has an average depth of four feet and a theoretical detention period of slightly over one day. The pond is cleaned in the summer before the sugar processing begins. Pond effluent is screened and pumped to the Sacramento River several hundred feet above the plant intake.

Water Pollution Control Board Requirements. Resolution No. 58-29, April 24, 1958:

1. The waste discharges shall not cause the dissolved oxygen content in the Sacramento River to be depressed below 5.0 parts per million at any time;
2. The waste discharges shall not contain more than 0.5 ml/liter of settleable solids;
3. The waste discharges shall not contain more than 15 parts per million ether soluble materials;
4. The waste discharges shall not cause objectionable discoloration of the Sacramento River;
5. The waste discharges shall not cause unsightly fungus growths in the Sacramento River;
6. The waste discharge shall not contain visible solids of recognizable waste origin;
7. The waste discharge shall not contain any substances in amounts which would be injurious to human, plants, animal or aquatic life;
8. The pH of the waste discharges shall be maintained between the limits of 6.5 and 8.5;
9. The waste discharge shall not contribute 5-day BOD to the Sacramento River at a rate exceeding the calculated by the formula:

$$\text{Maximum 5-day BOD discharge rate} = \frac{\text{Sacramento River Flow} \times 15{,}000}{6500 \text{ second-feet}}$$

The Sacramento River flow shall be taken as the reading at the "M" Street gage in Sacramento. The maximum discharge rate for the 5-day BOD will be 15,000 lbs./day when the river flow at the City of Sacramento is 6500 second feet;

10. Neither the waste discharges nor their disposal shall result in public nuisance by reason of odors or unsightliness.

The company carries out a routine monitoring program during the operating season. Samples are collected from the Sacramento River at two upstream and four downstream stations for BOD, Do and temperature determinations. Pond effluent is analyzed for BOD and pH. Results of analyses on the pond effluent are listed in Table 3.17.

Table 3.17

ANALYSES OF POND EFFLUENT *
AMERICAN CRYSTAL SUGAR COMPANY

	8/17/60	8/21/60	9/11/60	9/25/60	10/4/60	10/18/60	11/6/60	1/18/61
BOD (20°C), ppm								
3-Day	555	505	439	289	316	285	218	445
5-Day	565	540	461	300	326	320	230	445
7-Day	475	550	493	325	342	330	240	445
10-Day	590	554	538	325	360	355	255	
pH	5.8	6.6	6.9	9.3	7.1	7.2	6.8	6.6

* Analyses performed by the American Crystal Sugar Company.

Thirty-three samples of pond effluent were collected for 5-day BOD analysis during three 4-day periods in 1960 as a part of the Sacramento River Water Pollution Survey with the following results.

	5-Day BOD, ppm	Flow, MGD
Maximum	530	3.90
Minimum	250	3.09
Average	408	3.65

Average pounds BOD to river = 12,100 lb./day.

Future Industrial Waste Discharges

The Ralph L. Smith Lumber Company, a division of the Kimberly-Clark Corporation, proposes to construct a paper mill at Anderson in the near future. The proposed plant will have an ultimate production capacity of 150 tons of ground paper pulp, 300 tons of bleached sulfate pulp, 400 tons of printing paper, and 75 tons of tissue paper. The process water is to be treated and discharged to the Sacramento River below Stillwater Creek. The estimated waste water discharge will be 22 MGD and will constitute the largest separate industrial waste discharge to the river. Waste discharge requirements have been established by Resolution No. 61-28, March 2, 1961, and waste water and river water monitoring programs will be carried out by the company.

The U. S. Plywood Corporation is contemplating the construction of a 140 ton per day semi-chemical pulp mill and fibreboard plant north of Anderson. The maximum expected waste water flow will be 1.12 MGD. The waste water will be discharged to the Sacramento River at mid-stream via an underwater distribution pipe. At present, a pilot plant has been constructed and operated.

Agricultural Drainage

Most of the agricultural return water is discharged into the river between mile 100.1 and mile 80.8. There are four major and a number of minor drains that discharge agricultural irrigation waste into the river.

Table 3.18

DISCHARGES FROM IRRIGATION DRAINS
TO THE SACRAMENTO RIVER, 1950-59

	Discharge (1000 acre-feet)									
	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
Butte Slough	228	168	104	181	205	180	141	122	83	128
Reclamation District 70	16	18	33	31	36	24	34	15	36	21
Reclamation District 108	121	159	172	141	167	126	132	93	151	111
Reclamation District 787	6	9	19	22	19	11	27	13	22	16
Colusa Basin Drain	261	310	225	305	271	355	326	353	236	356
Sacramento Slough	338	335	200	180	345	445	276	246	370	232
Natomas Cross Canal	172	N.R.	214	81	83	107	152	48	12	4
Reclamation District 1000	43	38	77	45	46	51	65	17	82	9
TOTAL	1,184	1,037	1,043	987	1,172	1,298	1,152	907	992	877

Table 3.18 indicates that the total irrigation waste discharged from the eight drains is over 35 percent of the total amount of water diverted for irrigation between Sacramento and Redding. Since the overall Sacramento Valley irrigation water service area efficiency is approximately 60 percent, practically all of the unused applied irrigation water returns to the river by the drains listed in the table.

The discharge from Butte Slough, located four miles east of Colusa at river mile 138.9, is regulated by gravity culverts. During the summer months, the flow is made up almost entirely of return water from lands irrigated by diversions from the Feather River.

Reclamation District 108 pumps agricultural drainage into the Sacramento River at mile 100.1. The major portion of the pumping is done

after 10 p.m on week days and on weekends. On occasions, during periods of high runoff and precipitation, some of the drainage is diverted from the R. D. 108 channels into Colusa Basin Drain. During May 1959, the amount pumped averaged 390 cfs for a total of 24,000 acre-feet, 22 percent of the year's total flow.

Colusa Basin Drain, the largest individual irrigation drain discharging to the Sacramento River, is located at Knights Landing, mile 90.2. Flow is chiefly drainage from lands irrigated by seven large irrigation districts. Flow regulating outfall gates are located at the mouth of the drain. When there is a high flow in the channel an undetermined amount of water is diverted from the drain to Yolo Bypass via the Ridge Cut at Knights Landing.

During the sampling program of this survey, the maximum mean flow from Colusa Drain, 1,150 cfs, occurred in April 1960. At time of high flow in the river the outfall gates automatically close to prevent flow reversals in the channel. This usually happens sometime between the last of December and the first of March. During 1959, September was the month of highest flows when the mean daily flow was 1,232 cfs.

Flow from Sacramento Slough to Sacramento River consists of the combined flows from Reclamation District 1500 and Sutter Bypass. Located southeast of Knights Landing at river mile 80.8, the slough lies within Sutter Bypass and during periods of high river flows, is entirely submerged. Rises in the river stage cause reversals of flow in the slough. Discharges from Reclamation District 1500 into Sacramento Slough cause large variations in flow from the slough. During 1959, May was the month of highest total flow from Sacramento Slough with a mean daily flow of 980 cfs and a monthly total was 60,280 acre-feet.

The remaining four drains discharge a total quantity of water equivalent to flow from Butte Slough. On the average, since 1950, the small drains discharged a total of 187 acre-feet annually.

A water conduit for disposal of irrigation drainage, sewage, and industrial wastes in the Sacramento Valley has been considered in The California Water Plan. This conduit would begin at Redding, traverse the valley along the west side of the Sacramento River, and terminate in either the Sacramento River Deep Water Ship Channel or in the Sacramento-San Joaquin Delta.

Water Quality Management

The need for proper treatment of domestic and industrial wastes prior to disposal to the Sacramento is implicit throughout this chapter. Knowledge of the characteristics and timing of irrigation return flows is also essential. Any use of water inevitably results in some degradation. Even in the natural hydrologic cycle, water can only become more mineralized.

Optimization of all beneficial uses is dependent upon knowledge of the sources and effects of all types of degradation. The simplest and most known obvious method of water quality control is dilution and it is possible that reservoir releases may be made for this purpose. These considerations are developed in more detail in Appendix B.

CHAPTER X. SALINITY REPULSION

The lower reach of the Sacramento River is subject to salinity incursion from the ocean. The extent of this incursion is governed by the height of the tidal wave and the flow in the river.

Natural fresh water outflow from the Central Valley is inadequate to repel salinity during summer months. The maximum recorded extent of salinity incursion occurred in September 1931, when ocean salts reached 35 miles upstream in the Sacramento River.

The control of sea-water invasion can be most economically effected by repelling the saline water with fresh water released from upstream reservoirs. This has been provided in the plans for the Central Valley Project and in the operation of Shasta and Folsom Dams. Since operation began in 1949, invasion of sea water into Sacramento River has extended only to mile 7.0. Without such operational releases, in 1955 saline water would have intruded about 90 percent of the delta channels. The estimated minimum outflow to control salinity in the delta is 4,500 cfs, of which 3,300 cfs is measured outflow, and the remainder is unmeasured accretions in the delta.

Reservoir releases for salinity control are coordinated with releases for navigation, hydroelectric power generation, and other beneficial uses of the water.

CHAPTER XI. SUMMARY AND CONCLUSIONS

The Sacramento River is used for domestic, irrigation, and industrial water supplies, electric power generation, recreation, fish and wildlife propagation, navigation, salinity repulsion in the delta, and for disposal of wastes. During high flow months, these uses are affected by flood-control operations.

The estimated 1960 and 1990 urban and irrigation development and demands in northern Central Valley counties are

	1960	1990
Population	1,142,420	3,092,400
Urban area, acres	143,000	336,000
Urban water demand, acre-feet per year	225,000	745,000
Irrigated land, acres	1,900,000	2,747,000
Irrigation water demand, acre-feet per year	7,243,000	9,943,000

There are five water supply systems that divert and treat river water for domestic use: Redding, Rockaway, Enterprise, Sacramento, and Vallejo.

Most industrial demands are met by municipal water supply systems, although some water is diverted directly from the river.

Recreation has been developed into a billion-dollar industry in California and includes hunting, fishing, boating, camping, picnicking and water contact sports. Along the Sacramento River there are approximately 68 public landings, parks, resorts, and harbors that provide for boating and fishing needs; many offer overnight accommodations. On the Labor Day weekend, September 3 - 5, 1960, 2,584 boats were observed on the river

between Hamilton City and Rio Vista using Sacramento River recreation facilities.

The importance of the Sacramento River to fish and wildlife is evidenced by normal minimum fish releases of from 2,300 to 3,900 cfs from Shasta dam and by diversions for wildfowl habitat through the Delta-Mendota Canal.

A navigation requirement of 5,000 cfs passing the navigation control point near Wilkins Slough is established to provide for shallow-draft navigation as far upstream as Colusa. A channel depth of six feet is maintained between Colusa and the City of Sacramento. In the reach downstream from the City of Sacramento a depth of ten feet is maintained. It is estimated that in 1960 a total of 5,550,000 tons of commercial products were shipped through the Sacramento River's navigation system.

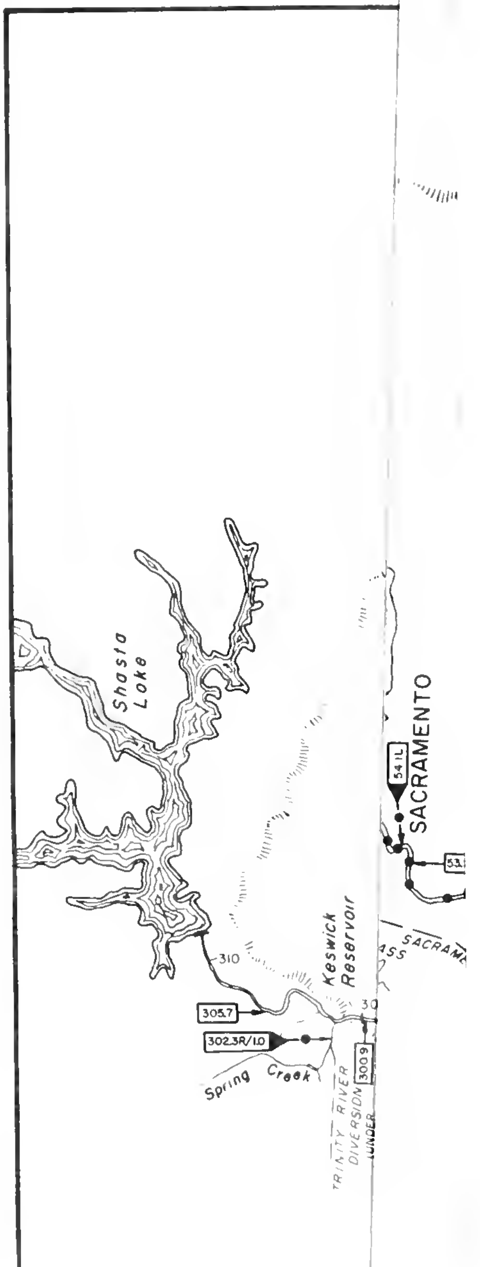
In 1960, an average of 56 million gallons per day was discharged directly to the river from primary sewage treatment plants serving Redding, Red Bluff, Corning, West Sacramento, Sacramento, Isleton, and Rio Vista. Discharges from other sewage treatment plants in the greater Sacramento area reach the river indirectly by means of drains and tributaries.

There are only two significant separate industrial waste discharges to the Sacramento River; a wood processing plant near Red Bluff and a sugar beet processing plant at Clarksburg. Five large canneries, a detergent plant, and numerous small industries discharge wastes through the Sacramento sewerage system. Slaughterhouses, dairies, canneries, and olive processing plants are connected to other sewerage systems that discharge to the river.

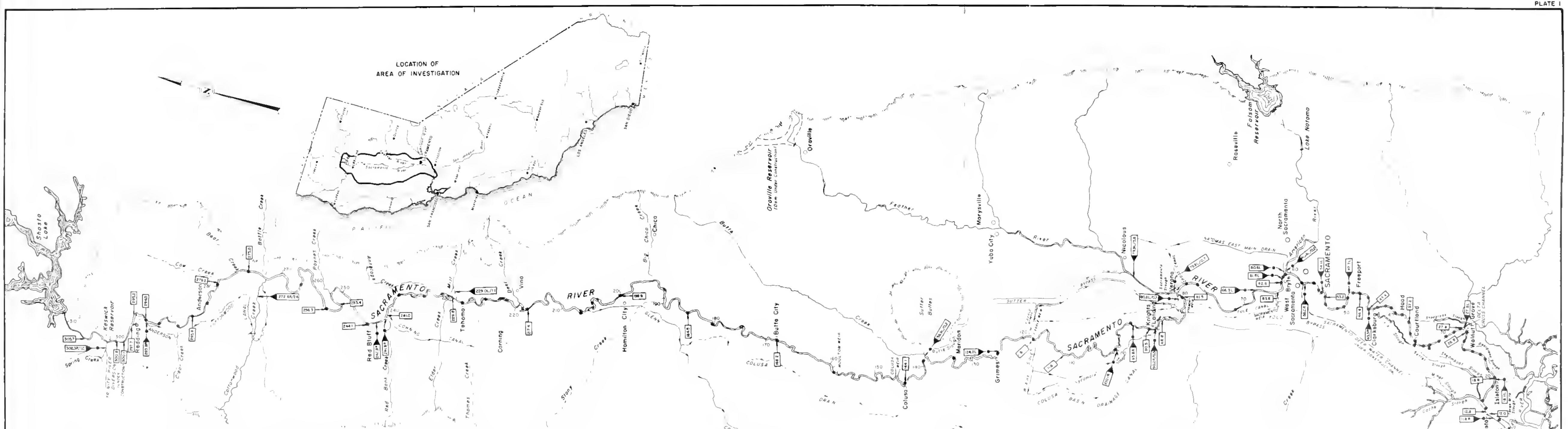
Total agricultural waste discharged to Sacramento River from the eight major drains has averaged over one million acre-feet annually

from 1950 through 1959. Of this amount 300,000 acre-feet was from Colusa Basin Drain, the largest individual irrigation discharge on the river.

Salinity incursion in the delta is controlled by fresh water released from the upstream reservoirs of Shasta and Folsom and from various waste discharges. The estimated outflow to the maintained in the delta to repel sea water is 4,500 cfs.



	LOCATION OF SAMPLING STAT RIVER MILE.
WASTE	SEWAGE TREATMENT PLANT DUSTRIAL WASTE DISCHARGES MONTHLY
MONTHLY	SAMPLED ONCE OR TWICE MO PHYSICAL, CHEMICAL, AND ANALYSES
DAILY	SAMPLED MONTHLY OR BIMO PLANKTON, BOTTOM ORGANI MENT GRADATION, DISSOLVE AND TEMPERATURE
BIOLOGIC	SAMPLED DAILY FOR TEMPE ELECTRICAL CONDUCTANCE ANALYSES OF COMPOSITE SA
ORGANIC	PERIODIC ORGANIC ANALYSE USING CARBON ADSORPTION
E C	CONTINUOUS ELECTRICAL RECORDER.



LOCATION OF SAMPLING STATION, RIVER MILE	WASTE: SEWAGE TREATMENT PLANT AND INDUSTRIAL WASTE DISCHARGES, SAMPLED MONTHLY	MONTHLY: SAMPLED ONCE OR TWICE MONTHLY FOR PHYSICAL, CHEMICAL, AND OXYGEN ANALYSES	DAILY: SAMPLED MONTHLY OR BIMONTHLY FOR PLANKTON, BOTTOM ORGANISMS, SEDIMENT GRADATION, DISSOLVED OXYGEN AND TEMPERATURE	BIOLOGIC: SAMPLED DAILY FOR TEMPERATURE AND ELECTRICAL CONDUCTANCE. CHEMICAL ANALYSES OF COMPOSITE SAMPLES	ORGANIC: PERIODIC ORGANIC ANALYSES SAMPLING USING CARBON ADSORPTION METHOD	E C: CONTINUOUS ELECTRICAL CONDUCTIVITY RECORDER
305.7		x		x		
302.3R/1.0		x				
300.9			x			
300.4		x				
297.7		x		x		
295.[illegible]				x		
294.0				x		
291.8R	x	x				
285.9		x		x		
279.[illegible]				x		
275.[illegible]		x		x		
272.4R/2.4		x				
256.[illegible]		x		x	x	
253.4				x		
244.1						x
242.9R	x	x				
241.9R	x	x				
241.0				x		
229.8		x		x		
229.0L/1.1		x				
217.[illegible]		x		x		
199.6		x	x	x		
184.[illegible]		x		x		
168.2		x		x	x	
144.1		x		x		x
138.9L/0.2		x				
124.2L		x				
118.1		x		x	x	
111.6					x	
100.1R					x	
93.6R		x				
90.5		x	x	x		x
90.2R/0.1		x	x	x		x
88.8				x		
81.5		x		x		
80.8L/0.7		x		x		
79.9L/5.8						x
79.9L/0.7		x				
66.3L		x				
63.6						x
62.5		x	x	x	x	
61.5L		x				
60.6L				x		
60.4L/0.2		x				
48.0R	x	x				
54.1L						
53.2	x	x		x		
47.7L	x					
46.4		x		x	x	x
43.4		x		x		
43.3R	x	x				
37.2		x		x		
27.4		x		x		
27.3L		x				
26.9			x			x
18.8		x		x		
18.1L	x					
12.8		x		x		
12.0		x				
11.6R	x					
4.0		x		x		

LEGEND

RIVER STATION

TRIBUTARY, IRRIGATION DRAIN OR WASTE DISCHARGE STATION

STATION SAMPLED AT 3 HOUR INTERVALS FOR 96-HOUR PERIODS

150 MILES ABOVE COLLINSVILLE

RIVER MILE AND BANK

138.9L/0.2 MILES UPSTREAM FROM MOUTH

APPROXIMATE EDGE OF VALLEY FLOOR

STATE OF CALIFORNIA
THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DELTA BRANCH

SACRAMENTO RIVER WATER POLLUTION SURVEY

SAMPLING PROGRAM AND AREA OF INVESTIGATION

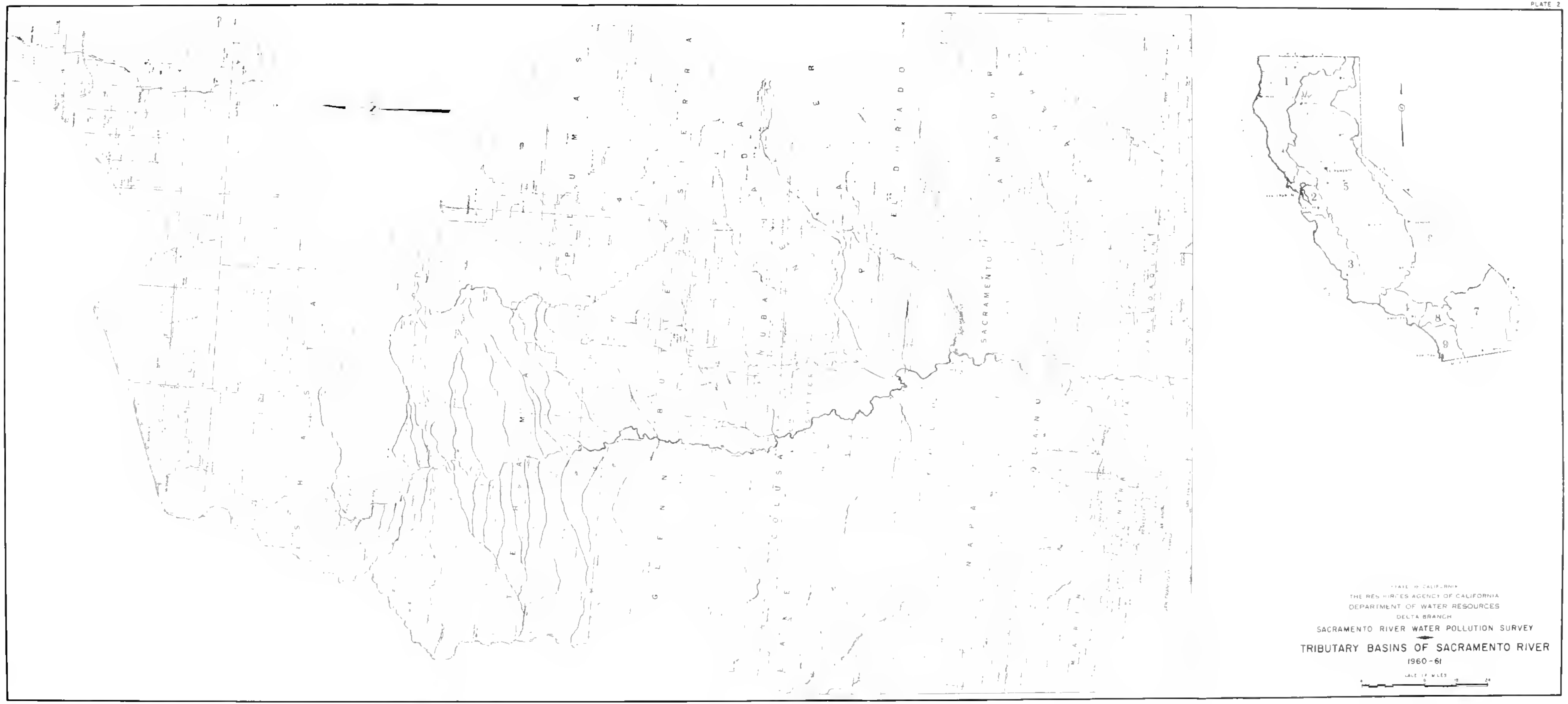
1960-61

SCALE IN MILES

0 5 10

PLATE 2

LEGEND



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